



**US Army Corps
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Engineer Research and
Development Center

A Catalog of Applications for Classified and Declassified Satellite Imagery

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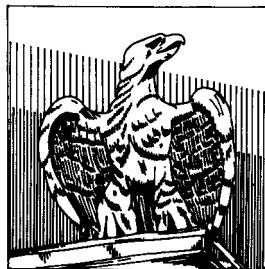


United States Department of Defense Legacy Resource Management Program

The Legacy Resource Management Program was established by the Congress of the United States in 1991 to provide the Department of Defense (DoD) with an opportunity to enhance the management of stewardship resources on over 25 million acres of land under DoD jurisdiction.

Legacy allows DoD to determine how to better integrate the conservation of irreplaceable biological, cultural, and geophysical resources with the dynamic requirements of military missions. To achieve this goal, DoD gives high priority to inventorying, protecting, and restoring biological, cultural, and geophysical resources in a comprehensive, cost-effective manner, in partnership with Federal, State, and local agencies, and private stakeholders.

Legacy activities help to ensure that DoD personnel better understand the need for protection and conservation of natural and cultural resources, and that the management of these resources will be fully integrated with, and support, DoD mission activities and the public interest. Through the combined efforts of the DoD components, Legacy seeks to achieve its legislative purposes with cooperation, industry, and creativity, to make DoD the Federal environmental leader.



This document is a Legacy Program work product and does not suggest or reflect the policy, programs, or doctrine of the Department of the Army, Department of Defense, or United States Government.

Cover image: 3-D representation of land use coverage as derived from 1965 declassified satellite imagery in conjunction with a 1972 Landsat MSS image.

Foreword

This research was conducted for the Legacy Resource Management Program under the auspices of the Office of the Deputy Under Secretary of Defense for Environmental Security, ODUSD(ES). Funding was accomplished under Military Interdepartmental Purchase Request number W31RYO91603438, "User Catalogue of Classified Imagery Applications to Military Test and Training Lands," Work Unit S80. The technical monitors were L. Peter Boice and Bruce Beard.

This work was performed by the Ecological Processes Branch (CN-N) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The CERL principal investigator was Robert C. Lozar. Wade Smith is a senior researcher with Mitretek Systems, 7525 Colshire Dr., McLean, VA 22102-7400. Hazekiah Adeyemi and Olayiwola Taylor are from the Department of Mathematical Sciences, and Musa Danjaji is from the Electronic Commerce Resource Center, Clark Atlanta University, Atlanta, GA. Renee Jacokes is from the Department of Geospatial Services, Georgia Institute of Technology, Atlanta, GA. M. Norman Malinas is from ERIM International, Ann Arbor, MI. Tereza Flaxman and Allan Shearer are from the Graduate School of Design, Harvard University, Cambridge, MA. Stephen E. Hodapp is Chief, CN-N, and Dr. John Bandy is Chief, CN. The staff from many U.S. Army installations provided data. Additional data were acquired from the U.S. Geological Survey (USGS) in Sioux Falls, SD. The technical editor was Gloria J. Wienke, Information Technology Laboratory. The associated Technical Director was Dr. William D. Severinghaus. The Acting Director of CERL is Dr. Alan W. Moore.

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1 Introduction

Background

There exists within the community of military installations a great interest in the massive amount of remotely sensed national defense intelligence data collected during the Cold War era (Lozar et al. 2000). These data include satellite-based photography and digital imagery gathered from a variety of instruments and could be of practical use to military land managers. The imagery remained highly classified for many years so the collected materials and supporting technologies remained inaccessible to potential users.

On 22 February 1995 Presidential Executive Order 12951 (Appendix A) initiated the framework for the declassification and public access of some of this material. A group of scientists, named the Government Applications Task Force (GATF), reviewed the feasibility of applying national imagery assets to questions of a nontactical nature and provided encouraging recommendations for the civilian use of this material. However, none of the examples generated by the GATF dealt specifically with military land management issues. Further, most of these studies were based on remotely sensed information available only to an audience with the appropriate clearance level. Though the photographic and digital images might provide unique opportunities for military land managers to carry out their responsibilities, the clearance required and the lack of specific land management examples made the technology transfer to installation staff slow.

In the summer of 1998 the Legacy Resource Management Program funded an investigation into how managers at military installations could apply this data to local land management issues. Two phases for the investigation were outlined. Phase I was an objective, systematic, and broad investigation of potential installation user needs in relation to the imagery available. *Removing the Veil* (Lozar et al. 2000) represents a summary of that first phase of research across Air Force, Army, Marine, and Navy installations. The survey conducted for Phase I found that managers were enthusiastic about potentially using remotely sensed material for local land management needs, but they generally wanted to see examples of what is available, particularly for their installation. The survey also concluded that service-wide, the installations are in a good position to begin to apply classified and declassified imagery for land management at installa-

tions. The staff is capable, interested, and has access to the technical resources to run sophisticated analyses if so desired. Some installations had already successfully applied the imagery. The most commonly requested applications were also those that are the easiest to carry out and provide the greatest cost savings. Access to secure resources on the installation and the need for clearances are not perceived as overwhelming obstacles. Funding is not perceived as a major issue, though this may change. However, to actually integrate the imagery into local evaluations, there was near unanimous agreement that examples and educational materials needed to be developed.

Objective

The overall objective of this research is to provide a service-wide user catalog of intelligence imagery applications for military land managers. This catalog (Phase II) provides examples of the different applications identified in Phase I as being of greatest interest to installation land manager's needs.

Approach

The purpose of Phase II of this research is to present realistic examples of the imagery as a set of applications intended to expose installation land managers to a variety of potential uses and the procedures by which these examples were generated. The results will be outlined so installation staff will be able to replicate them within their own offices.

To ensure the widest use of these applications, those illustrated in this catalog parallel those previously shown (Lozar et al. 2000) to have the best cost/benefit payback to the military. The applications chosen for inclusion are carried out at installations where the managers indicated the most interest in cooperating with this effort; however, with the exception of occasional guidance and base data support, no burden was put on the staff of the subject installations. Further, these examples are realistic; they are intended to be similar to a real analysis but should not be taken to imply that similar, real problems exist at the subject installations.

All the data and analysis techniques in these examples are unclassified so that many examples could be made available to a wide audience. Investigations dealing with materials still classified are underway.

This document is intended to provide some idea of the breadth (and limitations) associated with the imagery. Therefore, examples range from simply looking at images to carrying out sophisticated analyses using advanced Geographical Information System (GIS) and Image Processing (IP) techniques. The point is that there are a number of ways in which the material can be used.

Scope

The examples in this workbook are realistic; they are intended to be similar to a real analysis but are not analyses carried out at the installations. The applications chosen for inclusion are at installations where the managers indicated the most interest in cooperating with this effort and therefore are not intended to imply these are the most apt locations for the demonstrations.

To make many examples available to a wide audience:

1. All the data and analyses techniques in these examples are unclassified. The unattached appendices that are For Government Use Only will be made available only to the appropriate requestors. Investigations dealing with classified materials are underway.
2. The emphasis of this report is on what could be done with the imagery. Therefore, these procedures should be considered points of departure for how to carry out a similar procedure at any installation; they are not to be considered scientifically and statistically rigorous. In the same way, the statistical analyses should be considered examples rather than a base from which to draw conclusions.
3. Examples range from simply looking at images to carrying out sophisticated analyses using advanced GIS and IP techniques, to provide some idea of the breadth of potential applications.

The applications in this catalog focus on the needs of military installation land managers as determined in Phase I of the research. Though issues at particular installations are presented, these issues are common across all military services. This work integrates a coordinated similar effort being carried on at Mitretek Inc. (McLean, VA; point of contact: Wade Smith). These examples are intended to be useful throughout the Department of Defense (DoD). The applications are not intended to be actual solutions to real problems at any installation. They are intended to demonstrate that such applications are possible. The use of imagery from a particular installation for a particular application is not intended to suggest that the installation actually had such a problem. Though these applications parallel real problems, they are not necessarily addressing real problems at the particular installation.

This catalog does not cover all of the imagery data that might be available and it also does not represent all the potential applications. It does, however, focus on a set of applications that has been determined to be the most useful to installation personnel.

Mode of Technology Transfer

This catalog represents the primary means of technology transfer to the sponsor as a product. An accompanying CD-ROM product of samples of the data illustrated here is under development. Both are intended for use by military land managers, usually in the installation planning, forestry, natural resource, and environmental offices, normally in the Directorate of Public Works (DPW) or the equivalent.

2 The Imagery

Functionally, two types of imagery are available: unclassified and classified. The character and means by which each type can be acquired are different, depending on the category.

Unclassified Imagery Information

General information on the unclassified imagery data available to the public.

1. Images are available from satellites that were regularly imaging much of the United States almost from the beginning of their missions (as early as 1960).
2. Black and white photographic products of very high resolution for most U.S. installations can be expected to be available beginning with dates in the mid-1960s.
3. Acquisition cost is minimal and many organizations have the in-house resources to process the photographic material into digital form.
4. Enough data exists that one may confidently make the statement that some images will exist for most installations within the United States.
5. For many installations that do not have an alternative source of historical imagery, this is a unique archive that was not previously available.

KeyHole (KH) designators refer to the systems used aboard many different satellites launched to ensure continuous temporal coverage. All, however, are divided into the following imaging systems: the Corona System (includes KH-1-4, KH-4A, and KH-4B), the Argon System (KH-5), and the Lanyard System (KH-6). Most of the imagery of interest to military land managers falls into the following groups:

1. Before 1963, most of the film that is available (taken by the KH-5 Argon System operating from 1961 through 1964) covers nearly 500 by 500 kilometers (300 by 300 miles) per frame. If scanned at 765 linear dots per inch (dpi) resolution (equivalent to photographically enlarging 8 times to roughly a 1:500,000 scale map) will provide about a 140-meter on-the-ground resolution. That is, you may be able to see large buildings. Experience suggests lower resolution is likely. Figure 1 shows a gross scale, but it is the earliest imagery available. It has the potential of supporting regional analysis and some gross installation-specific questions. Notice the large area of coverage (280 miles on an edge). Also note the coastal clouds. With such a large area of coverage, clouds are likely to be present,

so it is wise to make sure you inspect the image before ordering. See the following section titled “Obtaining Unclassified Imagery.”

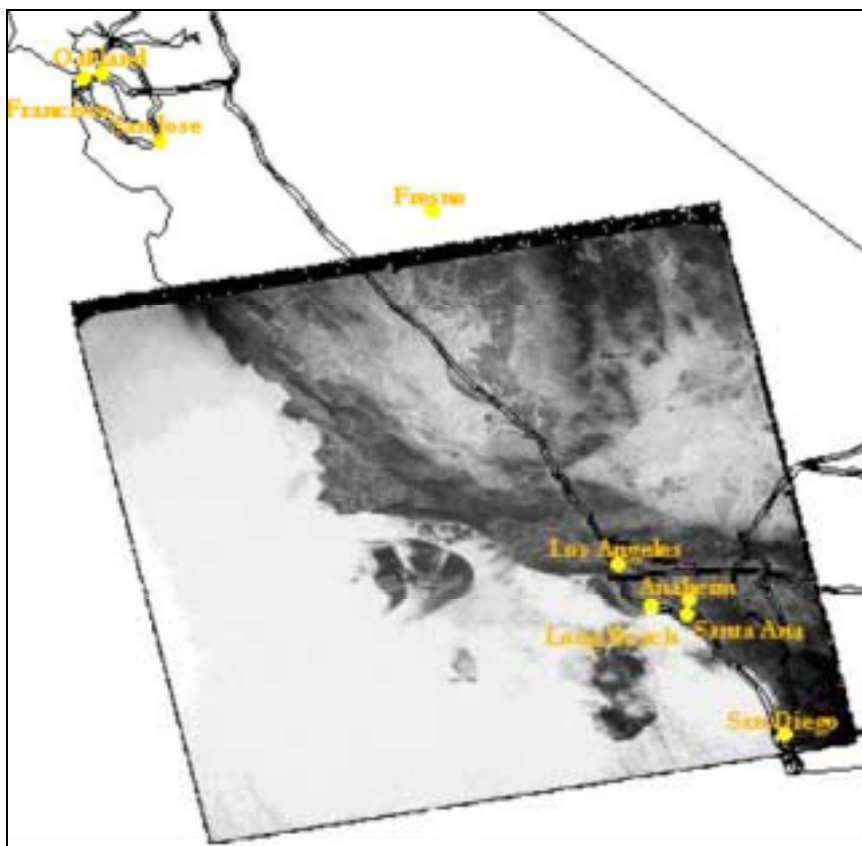


Figure 1. Georeferenced image from KH-5 Argon System taken of Southern California, 2 September 1963.

2. From roughly 1963 to 1969, film from the Corona KH-4A System (Figure 2) covered an area of approximately 16.6 by 230 kilometers (10.4 x 144 miles) and if scanned at 2850 dpi will provide about a 3-meter on-the-ground resolution. You can photographically enlarge the image 16 times to about a 1:20,000 scale map. The film shown in Figure 2 is about 2 in. by 30 in. It may be necessary to cut a film this size into shorter strips for scanning.
3. From roughly 1967 to 1972, film from the Corona KH-4B System covered an area of approximately 14 by 187 kilometers (8.6 by 117 miles) and if scanned at 3500 dpi will provide about a 2-meter on-the-ground resolution. You can photographically enlarge the image 16 times to about a 1:15,000 scale map. Coverage characteristics would be similar to those to the Corona KH-4A System example shown in Figure 2. In practice, scanning at a higher resolution (we adopted 5,000 dpi) resulted in a more versatile and visually acceptable image.
4. Images taken after 1972 remain classified.

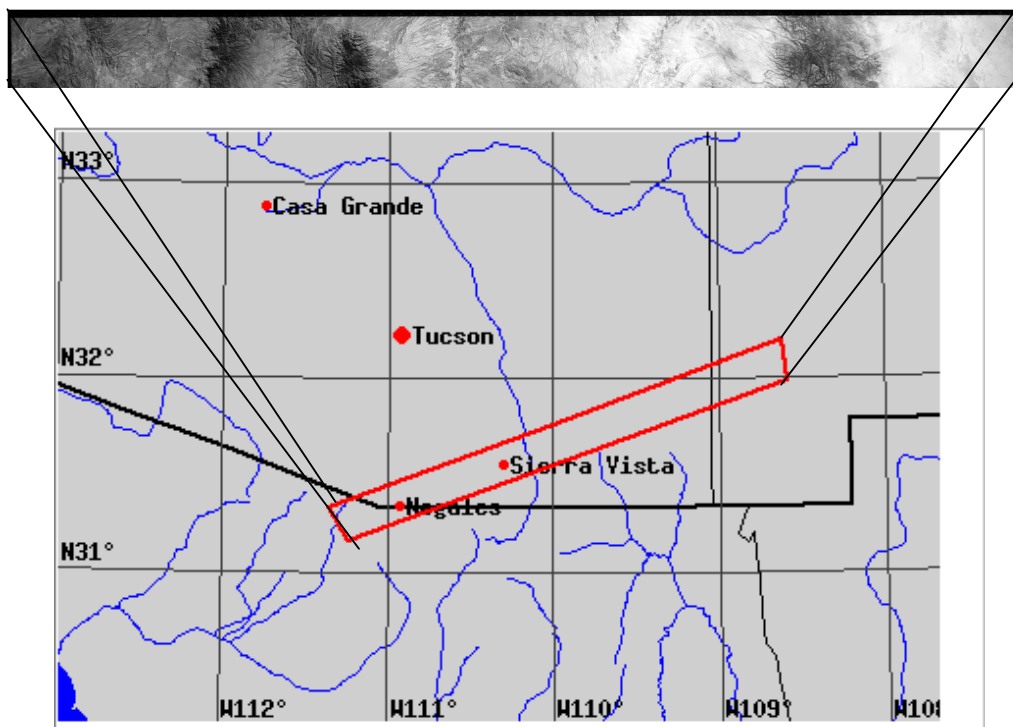


Figure 2. Example film image showing coverage for the Corona KH-4A System.

Since satellite orbits are not perfectly circular and atmospheric clearness varies a great deal, resolution and clearness can vary a good deal. For a detailed explanation of the declassified Corona satellite and imagery characteristics, refer to: <http://edcwww.cr.usgs.gov/Webglis/glisbin/guide.pl/glis/hyper/guide/disp>

Obtaining Unclassified Imagery

On 22 February 1995, the President, via Executive Order 12951, declassified early reconnaissance satellite imagery. The U.S. Geological Survey (USGS) Earth Resources Observation Systems (EROS) Data Center (EDC) operates an on-line Internet Web site for all their products at: <http://edcwww.cr.usgs.gov/webglis>

The site is scheduled to change to <http://earthexplorer.usgs.gov> in the Summer of 2001.

The unclassified imagery can be found in the category titled "Corona Satellite Photography." Highlighting this option will allow you to access an abstract or complete description, do a search for a particular area, and find out the price. In fact the entire search and order can be done on line.

You can refine your search by:











- Entering the region, or by clicking on a map screen to define the area,
- Entering the specific imagery acquisition period of interest,
- Restricting the search based on the availability of a small “browse” image of the photograph,
- Defining Mission Number,
- Defining Camera Type,
- Defining Camera Resolution,
- Defining Image Type, and
- Defining Film Type.

A successful search will result in a listing of candidate images (Figure 3). It is recommended you investigate the details on any image you contemplate ordering by clicking the “Detail” button shown in Figure 3. You can see if the geographical coverage is correct for your area and with the browse image, if the image is cloud free (Figure 4). Cost for an image is less than \$20. Once you have received the image, you can inspect the film or contact print directly or you can scan it. Once in digital format, georeferencing the image within the local GIS configuration for analysis and manipulation is appropriate. Thus, most of the cost is associated with formatting the material, not with the actual cost of the image.

CORONA Satellite Photography: Inventory Search Results

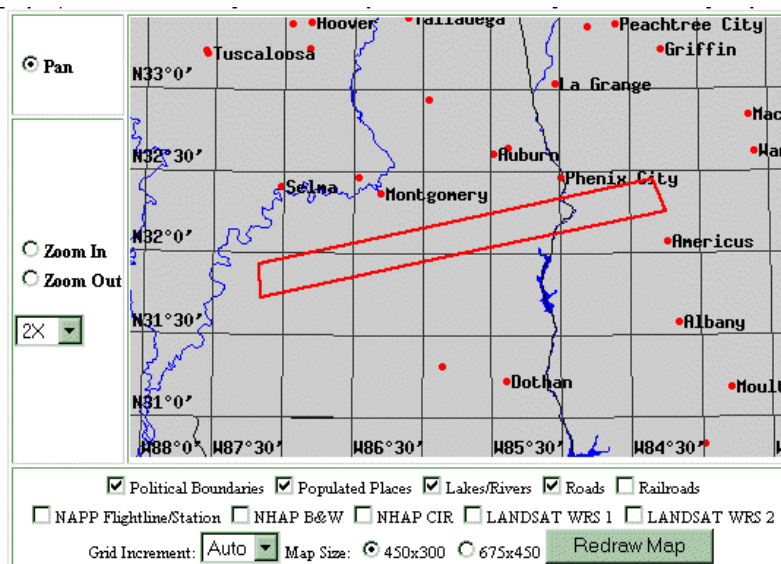
10 metadata records matched your query. Showing 1-10

To select an item for ordering, click on the ORDER button. To view detailed information and/or order individual items, click on the DETAIL button.

DISP Results									
DETAIL	ORDER	ENTITY ID	MISSION NUMBER	REVOLUTION	FR #	ACQ DATE	BR FL	CAM TYP	CAM RES
	<input type="checkbox"/>	DS1011-1030DF020	1011-1	030D	20	1964/10/07	Y F	4	
	<input type="checkbox"/>	DS1011-1030DF021	1011-1	030D	21	1964/10/07	Y F	4	
	<input type="checkbox"/>	DS1011-1030DF022	1011-1	030D	22	1964/10/07	Y F	4	
	<input type="checkbox"/>	DS1011-1030DF023	1011-1	030D	23	1964/10/07	Y F	4	
	<input type="checkbox"/>	DS1011-1030DF024	1011-1	030D	24	1964/10/07	Y F	4	
	<input type="checkbox"/>	DS1011-1030DF025	1011-1	030D	25	1964/10/07	Y F	4	
	<input type="checkbox"/>	DS1011-1030DF026	1011-1	030D	26	1964/10/07	Y F	4	
	<input type="checkbox"/>	DS1011-1030DF027	1011-1	030D	27	1964/10/07	Y F	4	
	<input type="checkbox"/>	DS1011-1030DF028	1011-1	030D	28	1964/10/07	Y F	4	
	<input type="checkbox"/>	DS1011-1030DF029	1011-1	030D	29	1964/10/07	Y F	4	

Generate Report	Add selected items from the current list to the Shopping Basket
Add all 10 items to the Shopping Basket	View Shopping Basket

Figure 3. Typical unclassified search result from USGS web site.



Note: Preview images are resampled from the original data and may not accurately represent the full resolution product. For more information see ["Overview of GLIS Preview Image Strategies"](#).

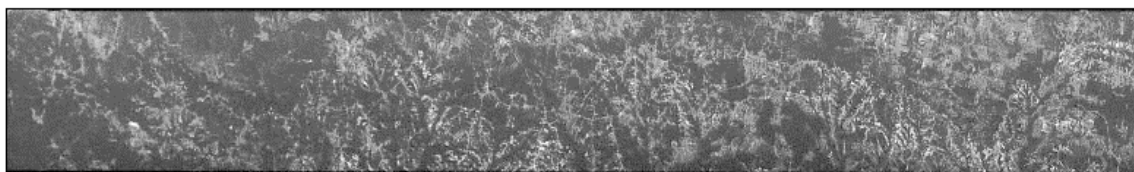


Figure 4. "Detail" results for a specific image.

Accessing and Processing the Films

As a test, searches were carried out for a sample (35) of the major Army installations in the United States. Each successful query of the Global Land Information System (GLIS) search engine returns a list of tens of feasible film negatives. However, many of these are not desired because the search engine will return all listings that touch the search region you define. You normally want the "bounding box" of the installation to be in or near the middle of a film strip. Locations near the right or left edge of the films are badly out of focus. It is advised to search only for films where a "browse image" (a small, low-detail digital image of the film) is available because some images are poorly exposed or cloud covered in the area of interest (AOI).

Film scanning was done for this catalog using two separate service bureaus (SpectraGraphics and Spectrum Color Lab) that had competitive pricing and service. Scanning can be costly, due both to the high resolution required (>2000 dpi) and the unusual film format (2.5 in. x 30 in.). For any large project you might want to consider negotiating a bulk contract discount.

The normal USGS order process is slow (up to 5 weeks) and rush fees are three times the normal price. Project planning should allow adequate lead time to receive the correct images. For example, in one instance during this test, the browse image showed a different film than the one ordered, which correctly covered the AOI. (Unfortunately, the correct images were also cloudy.) So, more than one round of ordering may be required.

No commercial process was found that could scan an entire 30-in. negative at full resolution. Drum scanners are available to process up to 24 in., but these are expensive (\$120 to \$150 for each film). In some cases, to get the film negatives scanned, we cut them into 5-in. segments with the loss of ¼ in. on each side. This did not allow for continuous coverage without purchasing and scanning dual sets of negatives. It also made georeferencing much more difficult.

Georeferencing Guidance

Due to the high resolution of the films, we decided that SPOT or LANDSAT TM* images were not adequate for georeferencing. Instead we obtained USGS Digital Raster Graphics - DRGs (scanned registered USGS quadrangle sheets) that covered each test installation. DRGs are available on CD from EROS Data Center or commercial firms such as Micropath Corporation (Golden, CO). DRGs are available for a small cost or service fee (in the range of \$45/quadrangle). DRGs were available for all but one test installation.

The DRGs formed an adequate basis for image registration. However, the extent of land cover change in the 30-year period between image acquisition and the USGS maps (DRGs) complicated the process. When the dates on the DRG and the image were similar, it showed clearly how inaccurate the DRGs can be. Also, you need to anticipate the disk space required for storing a large collection of raster images or you will spend substantial additional time and effort shifting files around between disks and tapes.

* Systeme Probatoire pour l'Observation de la Terra (SPOT) is France's earth observation satellite; information on Landsat Thematic Mapper (TM) electromagnetic imaging is available through the USGS web site.

All negatives need to be geographically registered. Unix workstations (SGI 02s and Sun UltraSparcs*) were used in this project, though PCs have the ability to do the same task more slowly. Image comparison tools such as the ERDAS Company's Imagine** "swipe" can prove invaluable in judging image alignment. Once ground control points are established, the program resamples the imagery to a new file, usually of about the same size or larger. Therefore, large amounts of additional disk space will be required for the georeferenced image.

Limitations

Limitations of the declassified imagery should also be recognized. Because it is uncalibrated panchromatic data with no infrared component, automated classification is not practical and distinctions within classes of vegetation are difficult. For quantitative work, Corona imagery may require careful and skilled photo-interpretation similar to that required for aerial photos.

If used in concert with other geographic data, satellite imagery can be used for the following four broad purposes.

1. As a qualitative visual reference base for comparison with contemporary panchromatic imagery of similar resolution, such as SPOT. By taking advantage of the pattern-matching abilities of the human visual system, a simple "dissolve" between historic and contemporary imagery can be very compelling. This approach avoids the time and expense of manual cover or feature classification.
2. As a basis for a coarse but comprehensive manual land cover classification (for example: urban, suburban, forest, meadow, riparian, wetlands, water, rock, snow, roads). Depending on the season of image acquisition and the expertise of the photo-interpreter, some additional classes of vegetation may be discerned.
3. As a basis for maps of specific changes in objects detectable in panchromatic imagery of this resolution. Examples might include comparisons of riparian vegetation over time, or stream channelization.
4. As a component to creating a historic vegetation map series and/or a vegetation dynamics model. Additional data that would contribute to such an endeavor would be soils type, soil moisture, fire regimes, fire history, elevation, slope, and aspect.

* Citing company names/products does not imply endorsement by the Corps of Engineers, U.S. Army, or Federal government.

** For more information, visit <http://www.erdas.com>

Limitations on Availability for Specific Installations

A very rough search was carried out for 35 representative Army installations (Table 1) to come to an understanding of the real availability of acceptable films.

Table 1. Specific installation search results.

Installation Name	Total Number of Films Found	Dates of the Films	Useable Images	Not Centered	Cloudy Images	Search Method
Fort Bliss, TX	69	1964/11/21 to 1967/09/01	0	60	9	By Name
Fort Lewis, WA	8	1970/03/10 to 1970/07/28	2	2	4	By Name
Dugway PG, UT	78	1962/02/27 to 1969/12/13	2	42	23	By Coordinates
Fort Eustis, VA	7	1963/12/26 to 1968/12/20	4	4		By Coordinates
Fort Irwin, CA	172	1962/06/28 to 1970/11/19	6	140	26	By Name
Fort Hood, TX	16	1964/06/09 to 1965/07/27	0	12	4	By Name
Fort Huachuca, AZ	99	1963/12/22 to 1972/04/29	13	64	22	By Name
Fort Greely, AK	7	1965/07/20 to 1969/09/23	1	6	0.5	By Name
Fort Richardson, AK	20	1968/11/03 to 1972/04/19	2	11	7	By Coordinates
Fort Wainwright, AK	6	1965/07/20 to 1969/09/23	1	4	1	By Coordinates
Yuma PG, AZ	100	1964/12/22 to 1972/04/28	3	80	17	By Coordinates
Fort Carson, CO	16	1961/10/13 to 1965/12/10	4	7	5	By Name
Fort Benning, GA	11	1964/08/08 to 1968/12/16	3	8		By Name
Fort Gordon, GA	22	24704	0	22		By Name
Schofield Barracks, HI	3	1969/03/21 to 1969/03/21	0	3		By Coordinates
Fort Riley, KS	3	25154	2	1		By Coordinates
Fort Leavenworth, KS	18	1965/10/30 to 1968/12/14	1	11	6	By Coordinates
Fort Knox, KY	24	1964/09/20 to 1968/05/01	2	18	4	By Name
Fort Campbell, KY	24	1964/10/07 to 1969/09/25	4	17	3	By Coordinates
Fort Polk, LA	6	25717	0	6		By Name
Camp Ripley, MN	3	25283	0	3		By Name
Camp Shelby, MS	5	1968/12/15 to 1969/09/25	1	2	2	By Coordinates
Fort Leonard Wood, MO	58	1964/08/08 to 1969/03/21	3	50	5	By Coordinates
White Sands MR, NM	79	1964/11/21 to 1967/09/19	1	62	12	By Coordinates
Fort Drum, NY	12	1964/09/18 to 1971/09/24	0	9	3	By Coordinates
Fort Pickett, VA	16	1964/11/26 to 1972/05/03	1	10	5	By Coordinates
Aberdeen PG, MD	23	1963/12/26 to 1967/08/17	3	10	10	By Coordinates
Fort Bragg, NC	12	1966/11/14 to 1967/08/07	1	9	2	By Coordinates
Fort Sill, OK	10	1964/06/09 to 1968/11/20	1	9		By Coordinates
Camp Bullis, TX	5	1964/02/19 to 1965/05/03	0	4	1	By Coordinates
Fort Sam Houston, TX	2	1964/11/27 to 1965/05/03	0		2	By Coordinates
Yakima TC, WA	8	1970/03/10 to 1970/07/28	1	7		By Coordinates
Camp McCoy, WI	2	1969/03/22 to 1969/03/22	0	1	1	By Name
Fort Jackson, SC	34	1967/06/18 to 1967/12/14	1	30	3	By Name
	Average: 29	Range: 1961 to 1972	Average: 2	Average: 22	Average: 7	

From the information listed in Table 1, one can expect that several tens of films will be found, that may be as old as 1961. Most will not be well centered, some will be cloudy, but normally there will exist a few that are acceptable for installation use. It should be mentioned that the search method, "By Coordinates" (latitude/longitude) has been determined to be less reliable in finding acceptable films than by defining a search region bounding box. A person familiar with the appearance of an area will be able to recognize where the installation is located within a browse film and can regularly increase the number of acceptable films.

To test the delivery system and quality of the product, as part of this work, several films were ordered, some of which were based in part on the search above, others on new searches (Table 2).

Table 2. Films for specific installations.

USGS ITEM #	Date	Location	Comments
DS1049-1047DF024	12/15/68	Camp Shelby, MS	
DS1040-2079DA008	4/4/67	Dugway Proving Ground, UT	Incorrect browse image
DS1040-2079DA009	4/4/67	Dugway Proving Ground, UT	Incorrect browse image
DS11080042145DA004	12/13/69	Dugway Proving Ground, UT	Correct coverage
DS009062077DA040	12/26/63	Fort AP Hill, VA	
DS009062077DF034	12/26/63	Fort AP Hill, VA	
DS009062077DA044	12/26/63	Fort AP Hill, VA	Too far South - missed AP Hill completely
DS1037-2095DF013	11/14/66	Fort AP Hill, VA	Too far South - missed AP Hill completely
DS1011-1030DF028	10/7/64	Fort Benning, GA	
DS1011-1030DF029	10/7/64	Fort Benning, GA	
DS1011-1030DF030	10/7/64	Fort Benning, GA	
DS1025-1031DF011	1965	Fort Benning, GA	
DS1049-1063DA014	12/16/68	Fort Benning, GA	
DS09058A031MC046	8/2/63	Fort Bliss, TX	Earliest Lo res
DS1014-1047DA017	11/21/64	Fort Bliss, TX	Higher (9 ft) resolution
DS1014-1047DF011	11/21/64	Fort Bliss, TX	Higher (9 ft) resolution
DS1101-1063DF012	9/19/67	Fort Bliss, TX	Highest (6 ft) res
DS1037-2095DA030	11/14/66	Fort Bragg, NC	
DS1011-1030DF015	10/7/64	Fort Campbell, KY	
DS1052-1047DA002	9/25/69	Fort Campbell, KY	
DS1019-1030DF035	5/1/65	Fort Campbell, KY	
DS1011-1030DA020	10/7/64	Fort Campbell, KY	
DS1025-1031DA017	10/7/65	Fort Carson, CO	
DS1025-1031DF011	10/7/65	Fort Carson, CO	
DS1016-1015DA044	1/16/65	Fort Carson, CO	
DS1016-1015DF039	1/16/65	Fort Carson, CO	
DS1014-2125DF016	11/26/64	Fort Eustis, VA	
DS009062077DA051	12/26/63	Fort Eustis, VA	
DS1052-1001DF012	9/22/69	Fort Greely, AK and Fort Hood, TX	All Dates Cloudy
DS1116-2161DA014	4/29/72	Fort Huachuca, AZ	Later Image
DS1017-1063DA015	3/1/65	Fort Huachuca, AZ	Northern
DS1017-1063DA016	3/1/65	Fort Huachuca, AZ	Southern
DS1017-1063DA017	3/1/65	Fort Huachuca, AZ	Southern

USGS ITEM #	Date	Location	Comments
DS1017-1063DF009	3/1/65	Fort Huachuca, AZ	
DS1037-1064DF007	11/12/66	Fort Huachuca, AZ	
DS1102-1048DF048	12/12/67	Fort Huachuca, AZ	
DS1046-2158DA038	3/24/68	Fort Huachuca, AZ	
DS1052-2177DF008	10/3/69	Fort Huachuca, AZ	
DS1017-1063DA015	3/1/65	Fort Huachuca, AZ	
DS1017-1063DF009	3/1/65	Fort Huachuca, AZ	
DS1021-1079DF014	5/23/65	Fort Huachuca, AZ	
DS1112-1048DA020	11/21/70	Fort Huachuca, AZ	
DS1112-1048DF014	11/21/70	Fort Huachuca, AZ	
DS1036-1016DF005	8/10/66	Fort Irwin, CA	
DS1104-2129DA026	8/15/68	Fort Irwin, CA	
DS1017-2095DF019	3/3/65	Fort Irwin, CA	
DS1021-2111DF011	5/5/65	Fort Irwin, CA	
DS1025-2127DF013	10/13/65	Fort Irwin, CA	
DS1025-2143DF007	10/14/65	Fort Irwin, CA	
DS1004-1047DF004	2/18/64	Fort Irwin, CA	Higher (9 ft) res
DS1013-1047DF012	11/5/64	Fort Irwin, CA	Higher (9 ft) res
DS1102-2079DF007	12/14/67	Fort Jackson, SC	
DS1011-1030DF009	10/7/64	Fort Knox, KY	Higher (9 ft) res
DS1019-1030DA033	5/1/65	Fort Knox, KY	
DS1011-1030DA014	10/7/64	Fort Knox, KY	
DS1026-1046DA009	10/31/65	Fort Leavenworth, KS	
DS1049-1031DF017	12/14/68	Fort Leonard Wood, MO	
DS1025-2110DF011	10/12/65	Fort Leonard Wood, MO	
DS1110-2210DF006	6/2/70	Fort Lewis, WA	
DS1110-2210DA012	6/2/70	Fort Lewis, WA	
DS1037-2095DF013	11/14/66	Fort Pickett, VA and Fort Polk, LA	All Dates Cloudy
DS1105-1001DA012	11/3/68	Fort Richardson, AK	
DS1116-1001DF016	4/19/72	Fort Richardson, AK	
DS1105-2144DF026	11/12/68	Fort Riley, KS	
DS1105-2144DA032	11/12/68	Fort Riley, KS	
DS1016-1062DF040	1/19/65	Fort Sill, OK	
DS009062077DA050	12/26/63	Fort Story, VA	
DS1052-1001DA007	9/23/69	Fort Wainwright, AK	
DS1006-1015DF042	6/5/64	Pinyon Canyon, CO	
DS1042-2105DA034	6/23/67	Sava River Bridge from Zupania, Croatia to Bosnia: Aft	
DS1042-2105DF034	6/23/67	Sava River Bridge from Zupania, Croatia to Bosnia: Forward	
DS1040-1038DA101	4/2/67	Thailand Peninsula - Aft	Stereo
DS1040-1038DF098	4/2/67	Thailand Peninsula - Forward	Stereo
DS1045-2173DF010	2/4/68	White Sand P. Ground, NM	
DS1110-2210DA017	6/2/70	Yakima Training Center, WA	
DS1028-1047DA007	12/27/65	Yuma Proving Ground, AZ	
DS1028-1047DA008	12/27/65	Yuma Proving Ground, AZ	
DS1028-1047DA010	12/27/65	Yuma Proving Ground, AZ	
DS1046-1079DA022	3/19/68	Yuma Proving Ground, AZ	
DS1046-1079DF022	3/19/68	Yuma Proving Ground, AZ	

From this list of 29 Army installations (and 2 overseas locations) the examples in this catalog were developed. It is worth noting that in most cases, film imagery was available for any given installation; only two locations had no acceptable film source. One might expect this to be the case for Fort Polk because Louisiana is often cloud covered. It was a surprise that for Fort Hood, located in a drier climate, all imagery was cloud covered for the dates samples were available.

Character of Currently Classified Imagery

A description of the characteristics of the still classified imagery cannot be covered in this document. For classified imagery, a reasonable person may assume:

- It exists after 1972.
- It is panchromatic (black and white) film-equivalent material.
- It will require a secure facility to handle.
- Coverage may be similar to the material already unclassified.
- The same techniques and limitations illustrated in these examples are likely to apply to the classified imagery.
- There is movement afoot to decrease the classification level on this newer material. This has been in review for several years and as of this writing date (April 2001) the material remains classified.

The labor, time, and resource commitment to handle these materials will be much greater than for unclassified materials. If what you want is the earliest imagery for a given location, the unclassified material should fulfill your needs adequately. If you need later archival imagery or need to request the acquisition of new imagery, expect a much longer response time than is characteristic of unclassified imagery.

Accessing Currently Classified Imagery^{*}

Appropriately cleared Federal Civil Agency personnel can access other satellite imagery that remains classified via the Civil Applications Committee (CAC).

^{*} Information in this section is from the source material in, "Civil Applications Committee, Civil Applications Training Program (on video Tape and CD) January 1, 1997." In fact, it is advised that anyone contemplating requesting classified material and holding the appropriate Secret Level Clearance review that introductory material.

The CAC was established in 1975 to ensure the effective application of data collected by the United States Imagery and Geospatial System (USIGS) for civil applications, including mapping, disaster assessments, monitoring environmental changes, supporting other scientific research activities relative to improving our knowledge of the Earth's environment, and for deriving other information needed to support national policies and objectives.

In 1992, Vice President Al Gore established the Environmental Task Force. In 1994, Congress directed that research be done to explore assisting Civil Agencies in accessing and using historical and current intelligence data for domestic functions and global change monitoring. Out of this research came the Environmental Program. Out of this program came studies referred to as the Government Applications Task Force Pilot Projects (GATF Pilot Projects). These study projects allow agencies to assess the benefits and shortfalls in using classified data. Though the use and handling of the data must be in a secure environment, in most cases the utility of this data far outweighs any shortfalls. Potential users should be aware that there exists vast amounts of both classified and unclassified historical data. This resource should be considered prior to requesting new data acquisition.

Currently, the operating assets are available on a "non-interference" basis for tasking assignment by the Civil Community. Even with the current intelligence requirements, civil and environmental needs are routinely satisfied. The USIGS community provides users assistance when requested to do so by the CAC. Civil and environmental uses of USIGS data (with limited exceptions) will always have a secondary priority to intelligence issues. Exceptions include USIGS support for natural and manmade disasters that threaten life and property.

All USIGS domestic collections require a Domestic Imagery Requirement (DIR) memorandum to ensure that the intelligence assets are not used to monitor U.S. persons.

The CAC is housed at the Advanced Systems Center in Reston, VA; the DoD point of contact is through the U.S. Army Engineer Research and Development Center/Topographic Engineering Center (ERDC/TEC) at Fort Belvoir, VA. Though the National Imagery and Mapping Agency (NIMA) has an Army Customer Support Center, ERDC/TEC is the appropriate contact for military land managers. Requests for images are submitted to the CAC collection management staff on standard request forms. The collection, distribution, and use of classified imagery of the United States must be validated by the chairman of the CAC and approved by the USIGS community.

When working on a classified project, individuals will often need to have access to classified information. An employee may be processed for a personnel clearance when a government agency determines that access is essential in the performance of tasks or services related to the fulfillment of a classified project. For a SECRET clearance, an employee must complete the Standard Form (SF) 86, Questionnaire for National Security Position and Fingerprint Card 258. A Letter of Notification of Personnel Clearance (LOC) will be issued to the Facility Security Office when an employee has been granted a personnel clearance. Prior to being granted access to classified information, the individual will sign the Classified Information Nondisclosure Agreement (SF 312) and receive an initial security briefing. The personnel Security Officer is responsible for initiating the personnel security clearance. Training for the handling and use of USIGS material is required to ensure that classification and use restrictions are clearly understood and followed by all users.

Satellite data comes in a variety of formats, both hard and softcopy. Imagery products include hardcopy images (flats), softcopy digital products, and a variety of custom products. The civil remote sensing capabilities traditionally include specific softcopy formats. When data is received from the Intelligence Community it is classified and must be handled accordingly. However, an unclassified product may be created if the user understands how to create it. Chairman of the CAC and the Director of the NIMA must approve the creation of an unclassified Imagery Derived Product (IDP).

Classified archived imagery data dates back to the early 1960s. Historical classified coverage can be requested through the National Area Coverage Data File (NACDF) and the NIMA. Custom products are value-added processing or non-standard products generated by the USIGS Community and the USGS Advanced Systems Center.

To acquire new classified data, users can expect to carry out a procedure similar to the following:

- Conduct all classified work in appropriately cleared facilities and communicate only over secure systems.
- Coordinate project approval through CAC representative.
- Submit draft Imagery Study Request (ISR) if required.
- Submit draft of DIR.
- Formulate initial collection strategy via tasking worksheet.
- Select target types and location.
- Research archive database for alternative data. (These include the EROS Data Center, the NIMA Mapping, Charting, and Geodesy [MC&G] data, the

National Area Coverage Data Files [NACDF], the CAC archive, currently available imagery.)

- Review collection strategy with collection manager via tasking worksheet.
- Build tasking sites based on target type and location.
- Review DIR.
- The CAC collection manager submits tasking requirement upon approval of the DIR.

The Director of the NIMA, with a recommendation from the Imagery Policy and Security Subcommittee (IPSCOM), will respond to an application for approval of an IDP technique within 90 calendar days of receipt.

Unclassified IDPs are to be created for official U.S. Government purposes only. IDPs are normally generated and distributed at the SECRET level without additional guidance from the IPSCOM. Organizations needing an UNCLASSIFIED IDP should first consider using unclassified commercial satellite or airborne imagery. If these sources are feasible and cost-effective, they should be used instead of classified USIGS data. Declassifying IDPs generates more useful products for civil agencies and environmental purposes, and for use in domestic and foreign crisis situations. However, information about the United States Imagery and Geospatial System must be protected in accordance with U.S. national defense and foreign policy. IDPs must meet specific technical criteria. Non-attributable information derived from these sources, when presented in a non-literal format (line drawing, map, map overlay) may be eligible for declassification. The Director of the NIMA, with a recommendation from the IPSCOM, will respond to an application for use of an approved IDP technique nominally within 5 working days of receipt and, when required, in a matter of hours. The requester will also identify the individual or organizational element with the responsibility for case-by-case review of IDPs prior to release at the UNCLASSIFIED level. To ensure compliance with the technique and use as approved by the Director of NIMA, the producer must review individual IDPs.

If USIGS data is being requested for the creation of UNCLASSIFIED IDPs, this fact must be included in or amended to the DIR. The producer must fill out an IDP Documentation Form each time an IDP is produced at the unclassified level. The producers must retain a copy of the documentation and the IDP for a minimum of 3 years after the IDP is created. NIMA can request a review of the IDP.

Though IDPs are unique for each request, there does exist a set of standard products available. (Unattached Appendix FGUO1 is For Government Use Only. The POC is Robert Lozar at ERDC/CERL [217] 352-6511 x6367 or Robert.C.Lozar@erdc.usace.army.mil).

Applications and uses of scientifically or environmentally valuable data (with limited exceptions) will always have a secondary priority to intelligence issues. Land managers' requests will rarely be given priority. The DoD is highly involved with operation of these assets. Therefore DoD land managers go through a unique request procedure compared to other Federal agencies. Installation land managers go through their Service-appointed CAC. All other agencies go through the USGS. This means that land manager requests are reviewed along with other requests that have an intelligence issue. Experience suggests that this results in response turn-around of at least months to a year or more, additional documentation, and possibly a refusal of the request.

A useful initiative, the Environmental Imagery Derived Products (EIDP) Program (see Appendix FGUO2), is sponsored by the DCI. The EIDP has among its objectives the purpose to satisfy application needs of US Government agencies at a lower classification level as derived from classified sources. (Unattached Appendix FGUO2 is For Government Use Only. The POC is Robert Lozar at ERDC/CERL [217] 352-6511 x6367 or Robert.C.Lozar@erdc.usace.army.mil.

If the application a land manager wishes to carry out requires classified imagery support, it should be recognized that the labor, time, and resource commitment to handle these materials will be much greater than one normally experiences. If a manager needs classified archival imagery or needs to request the acquisition of new imagery, expect a much longer response time than is characteristic of unclassified imagery. For many installations, the staff time resources may be too limiting to pursue the application procedure. An alternative is to assign the complete undertaking to a qualified contractor. A few contractors have applied for IDPs and successfully completed the application. Of course, this will require funding resources greater than would normally be the case for similar entirely civil contract tasks.

Experience during the current project suggests that the IPSCOM has a strong desire to recommend that nonclassified commercial resources be used instead to carry out an application. This recommendation has resulted even when making a request for unique archival imagery where no commercial alternative existed.

3 Catalog of Land Applications

To show how imagery can be applied to civilian needs, several examples have been developed. Though these are not specific to military installation users requests, they are presented in Appendix FGUO2 to provide a broader understanding of the capabilities of the currently classified imaging systems application capabilities. Appendix FGUO2 is For Government Use Only.

Catalog Background and Procedure

This section is a compilation of work done at the Construction Engineering Research Laboratory of ERDC (ERDC/CERL), Mitretek Systems Inc., Clark Atlanta University GIS Laboratory, and Harvard University Graduate School of Design. In it, these partners provide examples of how to use the declassified imagery to answer those questions identified in Phase I as of greatest interest to installation land managers. What follows are the applications with procedures for accomplishing realistic applications. The applications were not carried out at the installations and are considerably simplified here in order to make examples that are realistically based on the needs expressed by installation staff in a previous research (Lozar et al. 2000). Declassified imagery is used here as surrogates for resources that cannot be distributed.

For each application a standard format has been adopted for presentation where appropriate:

- application area
- installation location used
- description of need for this analysis
- general description of procedure
- imagery resources required
- specific procedure
- result
- conclusion.

Sample Applications

Group 1: Land Use Change

- Urban Land Use Change Analysis, Fort Huachuca, AZ
- Visualization Integration, Upper San Pedro River and Fort Huachuca, AZ

Group 2: Vegetative Change

- Wetland and Land Carrying Capacity for Military Use, Fort Story, VA
- Forestry Management, Fort Huachuca, AZ

Group 3: Habitat Change

- Habitat Change due to Road Encroachment Analysis, Sierra Vista, AZ and Fort Huachuca, AZ
- Aquatic Habitat Monitoring and Mapping, Naval Facilities Engineering Command (NFEC) San Diego Bay, CA
- Endangered Species Habitat Monitoring, NFEC San Clemente Island, CA

Group 4: Discovery of Disposal Sites

- Discovery of Unauthorized/Unrecorded Hazardous Disposal Sites, Dugway PG, UT
- Discovery of Unauthorized/Unrecorded Hazardous Disposal Sites, Fort Eustis, VA
- Oil Spill Damage in an Estuarine Environment, NFEC Roosevelt Roads Naval Base, PR

Group 5: Regional Change Monitoring

- Vegetation and Trend Analysis and Extending Management and Climate Change Trend Analysis Baselines, Yuma Proving Ground, AZ
- Vegetation and Trend Analysis and Support for Regional Ecosystem Management, Fort Benning, GA
- Extending Management and Climate Change Trend Analysis Baselines and Base Realignment and Closure (BRAC) Support, Pinon Canyon, CO
- Support for Regional Ecosystem Management, Fort Huachuca, AZ

Group 6: Base Realignment and Closure (BRAC)

- Determination of Predeployment Conditions, Sava River Crossing, Bosnia
- Determination of Predeployment Conditions, simulation for Tropical Test Center, Thailand

Group 7: Historical/Cultural

- Discovery of Former Training Range Types, Fort A.P. Hill, VA
- Cultural Resources Investigations, Edwards AFB, CA

Application Area: Land Use Change Investigations

Installation location used. Fort Huachuca, AZ

Description of need for this analysis. The ability to follow land use changes over time by using remotely sensed imagery has been identified (Lozar et al. 2000) as a base capability upon which many other applications are built.

General description of procedure. In this work, examples of Corona imagery have been applied to land use change analyses at Fort Huachuca, AZ. This work is representative of some of the most likely uses of this imagery within the context of a land management and environmental evaluation.

Working with Corona imagery is, in most ways, similar to using historic black and white aerial photography. However, unlike typical historic aerial photography, coverage extent is large (typically hundreds of square miles). This has the advantage of avoiding complex tiling and variable exposure problems of smaller independent images. However, it has the disadvantage of requiring a large computing infrastructure, and the single exposure may lose detail in brighter and darker areas of the negative. Increasing the dynamic range of the scanned image from 8 to 16 bits might alleviate some exposure problems, but currently yields an image of intractable size.

Because the imagery is panchromatic, manual photo interpretation is useful rather than automated classification. For these films, you are trading off spectral variation used in multi-spectral images for the very high degree of spatial resolution (about 2 to 3 meters). Air photo interpretation is a relatively expensive, time-consuming process, which requires significant expertise. Even with the relatively high ground resolution, taking advantage of the stereo pairs, where available, improves the ability to discriminate types of vegetation (e.g., shrubby species such as mesquite and creosote bush).

Based on the nature of the data, emphasis was directed to mapping human-dominated land cover types in this application. Urban infrastructure and roads are easily discerned in Corona imagery.

Imagery resources required. Four negatives for Fort Huachuca were scanned at 5000 dpi:

Film Item Numbers and Date	
DS1017-1063DA015	1/Mar/65
DS1017-1063DA016	1/Mar/65
DS1017-1063DA017	1/Mar/65
DS1017-1063DF009	1/Mar/65

Specific procedure.

1. **Georeferencing:** Because of the large extent of these images, 25 to 100 GCPs were used for georeferencing each image.

The Corona images have such a high resolution (Figure 5) more detailed base maps are required for georeferencing. To find appropriate georeference points, 1:24,000 scale USGS Digital Raster Graphics were used. Experiments were conducted with the use of alternative, lower resolution base data sources such as 1:125,000 scale USGS maps or Digital Line Graphics (DLGs). These alternatives did not provide sufficient numbers of appropriate GCPs visible in the Corona imagery.

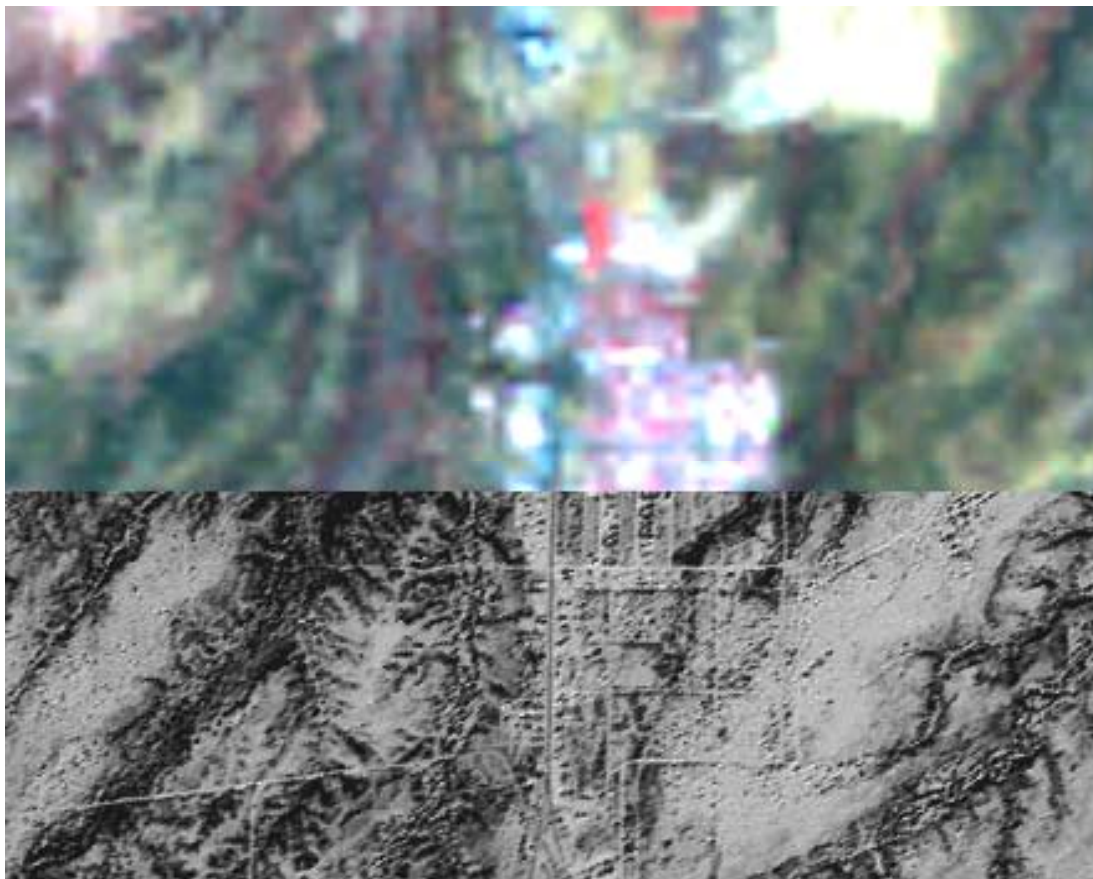


Figure 5. Fort Huachuca (left) and the town of Sierra Vista (right) with TM image (top) and Corona image (bottom).

The georeferencing process required about 15 DRGs to be mosaiced for an installation (at larger installations such as Fort Irwin, this amounts to 1.1 gigabytes of reference information). The Corona imagery itself scanned at 5,000 dpi occupies an additional 400 megabytes. While it is possible to down-sample either base imagery or the Corona scans, the resulting loss of clarity adds significantly to the georeferencing time required.

It is recommended that anyone attempting to georeference full Corona negatives be prepared to process very large data sets. This project made use of approximately \$20,000 worth of equipment (a Sun Sparc Ultra 10 and an SGI 02, each with a 16-gigabyte disk and >256M of RAM), yet the systems were taxed to their limits.

2. **Land Use Identification:** In performing land use change analyses, normal practice is to use consistent data and classification approaches for each time step, if possible. However, the earliest usable Corona imagery for Fort Huachuca was from 1965, and the latest from 1972. For planning and management purposes, looking at change during that short period is likely to be less compelling than comparing land use from the 1960s with current conditions.

Lacking fully comparable current data, an existing classification derived from high-altitude photography (Cablek and Mouat 2000) was used for the description of 1992 to 1997 conditions. The new Corona classification was matched as closely as practical to the 1992 classification, adjusting minimum mapping units and categories as necessary. This approach is necessarily less accurate than one based on identical data sources and classification pathways.

Firsthand knowledge of the area leads to the speculation that the minimum mapping unit sizes used probably under-predict the extent of low-density development outside of urban/suburban centers. Also, although large-roofed buildings were clearly visible within the Corona imagery, their functional classification into urban/commercial and industrial classes was based largely on context and auxiliary GIS data layers. Fieldwork should be carried out if it is desired that the mapped classes meet national map accuracy standards.

Corona interpretation (Figure 6) was done in ERDAS Imagine. USGS 1:24,000 scale topographic quadrangles were used as reference. The minimum mapping unit used was 1 hectare.

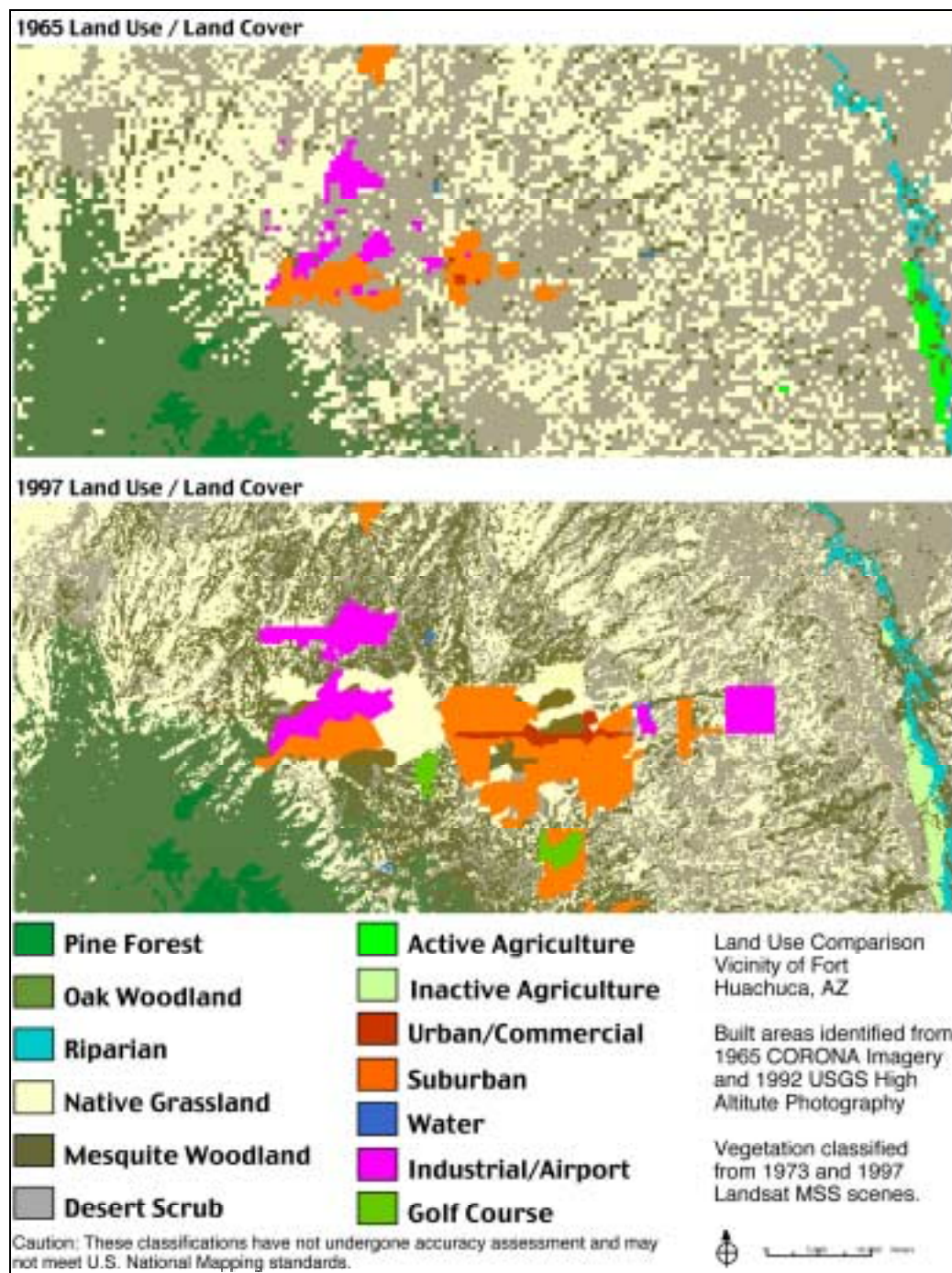


Figure 6. Comparison of land cover derived using 1965 Corona image, supplemented with 1973 Landsat MSS and professional photo analysis (top) and 1997 TM image classification (bottom).

Result.

1. **Analysis of Built Areas:** Notwithstanding the caveats, the overall extent of denser urbanization within the region is likely to be well captured under the classifications adopted for this application. Overall, we found (Table 3) a 2.7-fold increase in suburban area (1,524 hectares of new suburban development). Indus-

trial and airport area increased 2.4-fold (669 new hectares). Detected commercial area increased over 9-fold (164 new hectares). The increase in commercial area may be partially due to a known trend in retail development size. While few commercial areas were large enough to be visible in 1965 Corona imagery, much new commercial development with attendant large parking areas easily exceeded the 1-hectare minimum mapping unit threshold.

Table 3. Increase in new suburban development.

Built Land Use Change 1965 - 1992	Area 1965 (ha)	Area 1997 (ha)	Percent Change	Fraction Change	Difference in Hectares
Urban/Commercial	20	184	819%	9.2	164
Suburban	894	2,418	170%	2.7	1,524
Industrial / Airport	487	1,156	137%	2.4	669
Total	1,401	3,757	168%	2.7	2,356

2. **Analyses of Unbuilt Areas:** In a desert environment, roads down to the level of small jeep trails are clearly visible on Corona imagery. This allowed investigation into the change in the roadless area. Using the 1980 Tiger roads file from the U.S. Census Bureau, all roads not visible on the 1965 Corona negative were deleted from the Tiger data to make a new layer of road data. This technique was much more efficient than digitizing all roads from scratch, and gave us matching topology on the resultant road networks. The Tiger roads classification is very constraining. In the study area, roads with widely varying traffic loads are aggregated to a few classes. The primary impact of this classification scheme on change analysis is that it tends to overstate the importance of small, seldom used tracts, and to understate that of heavily used unpaved and semipaved roads.

The results are summarized in Table 4 and Figure 7. Most notably, the length of local and secondary streets approximately doubled during the period. Most of this increase was highly localized in areas immediately adjacent to previously developed areas.

It is more difficult to perform limited vegetation classification on the Corona negatives, for example in determining overall vegetative cover. Vegetation transitions hypothesized to have occurred over this time period involve mesquite encroachment into native grassland and mixed desert scrub communities. However, after reviewing the available imagery with a specialist familiar with land use change in the area (David Mouat, Senior Research Scientist, Desert Research Institute, Las Vegas, NV, professional discussion, 2000), it was determined that the imagery for 1965 had insufficient detail (both spectral and spatial) to allow confident recognition of mesquite vegetation change. Assessing changes in larger items (e.g., trees) is more likely to yield useful results. Fur-

thermore, lighting variation within the negative made measurement of overall vegetative cover impossible with available techniques.

Table 4. Summary of changes in the number and length of roads from 1965 to 1997.

Summary of Changes in the Numbers of Roads, 1965-1997

CFCC*	Description	Count 1965	Count 1997	Absolute Difference	Percent Difference
A00	Unclassified Road	331	443	112	34%
A21	Primary road without limited access, US highways, unseparated	108	113	5	5%
A31	Secondary and connecting road, state highways, unseparated	1	5	4	400%
A40	Local, neighborhood, and rural road, city street	192	396	204	106%
A41	Local, neighborhood, and rural road, city street, unseparated	2,956	3,830	874	30%
Total		3,588	4,787		33%

Summary of Changes in the Length of Roads, 1965-1997

CFCC	Description	Length 1965 (m)	Length 1997(m)	Absolute Difference	Percent Difference
A00	Unclassified Road	103,355	134,019	30664	30%
A21	Primary road without limited access, US highways, unseparated	29,973	32,361	2388	8%
A31	Secondary and connecting road, state highways, unseparated	93	194	101	108%
A40	Local, neighborhood, and rural road, city street	24,871	49,024	24153	97%
A41	Local, neighborhood, and rural road, city street, unseparated	768,376	928,905	160530	21%
Total		926,668	1,144,503		24%

* Census Feature Class Code



Figure 7. Increase in roads between 1965 and 1991.

Conclusion. For the purpose of detecting land use change, the Corona films offer some opportunities, as well as limitations. Quantifiable changes in the types of land use can be determined with good confidence because of the high resolution of the images. Important indices of natural condition, such as encroachment due to road building can also be quantified. Changes in grassland and scrub to mesquite land cover require more spectral and spatial resolution than the Corona images can provide.

Application Area: Visualization

Installation location used. Fort Huachuca, AZ

Description of need for this analysis. Individuals not in the land management field may have a more difficult time interpreting the results of two-dimensional maps. Making the point in a three-dimensional presentation, particularly one in which movement or change is evident, can deliver a land management point much more effectively.

General description of procedure. Please refer to sections: Habitat Changes (page 61) and Land Use Investigations (page 32) at Fort Huachuca for initial discussions.

An animated depiction of land use change and one of its potential impacts was developed. This product, in the format of a digital movie, shows a flythrough of the Corona imagery draped over terrain followed by a series of “before and after” simulated views.

Imagery resources required. 1965 Corona image, Digital Elevation Model (DEM), analyses generated in the sections titled Habitat Changes and Land Use Change Investigations.

Specific procedure. The 30-m USGS Digital Elevation Models were obtained for the area via the Internet. Multiple 1:24,000 scale quadrangles were mosaiced and clipped to the extent of the Corona negative west of the San Pedro River on Fort Huachuca.

The USGS mosaic DEM was exported from ERDAS Imagine to USGS DEM format. The Polytrans file format converter (Okino Software, Toronto, Canada) was used to create polygonal geometry within Alias/Wavefront Maya 2.5 (Toronto, Canada). The Okino plug-in was used to tile and resample the terrain geometry into manageable pieces for available computer hardware. Visualization work was performed on two machines: an SGI (Mountain View, CA) Visual Workstation dual 400-Mhz Pentium 2 workstation with 512M RAM, and an SGI 02 Unix workstation with 582M RAM.

The maximum practical terrain resolution for this region was 150 m. While this led to a distinct generalization of the terrain geometry, it was not a major issue for this example application. To compensate for the generalization, and for the narrow aspect ratio of the final movie presentation format, we exaggerated the vertical elevation of the terrain by a factor of 2.

The Corona imagery was resampled to 4-m resolution, again due to hardware constraints. Imagery and GIS data layers were exported from ERDAS Imagine as geoTIFF files. We then used the Maya tool “makebot” to create a MIPMAPed version of the image. The use of MIPMAPs progressively lowers image resolution based on the distance from camera of an image segment. The “.bot” file was texturemapped onto the terrain using the Unix version of Maya, since the Windows NT version does not currently support these files.

Animations and still frame images from a fixed camera position were rendered in Maya. This imagery was imported into a Media100 (Marlboro, MA) Video Editing package. Titles were generated using Adobe Photoshop 5.0 (Mountain View, CA).

Result. The movie starts in the south, from a high oblique position showing the Huachuca Mountains, Fort Huachuca, and the San Pedro River (Figure 8). The camera then zooms in on central Sierra Vista and back out to a view showing the entire town (Figure 9). The change in land use is shown using Corona for 1965 (Figure 10) and USGS aerial photography for 1997. The same change is shown using the imagery classified by land use (Figure 11).

The movie ends with a look at the impact of this land use change on the potential habitat of the Pronghorn Antelope, a grassland species (Figure 12).



Figure 8. Portion of starting frame of animation.

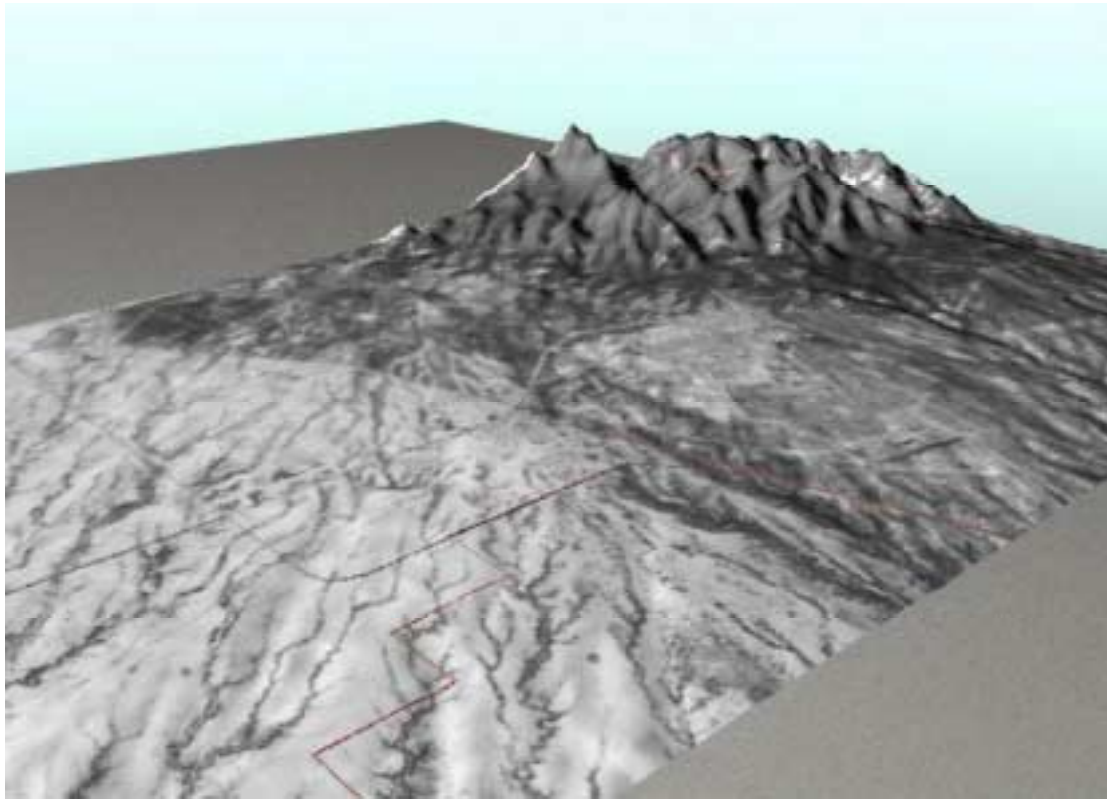


Figure 9. Simulated view of Sierra Vista 1965, looking southwest.

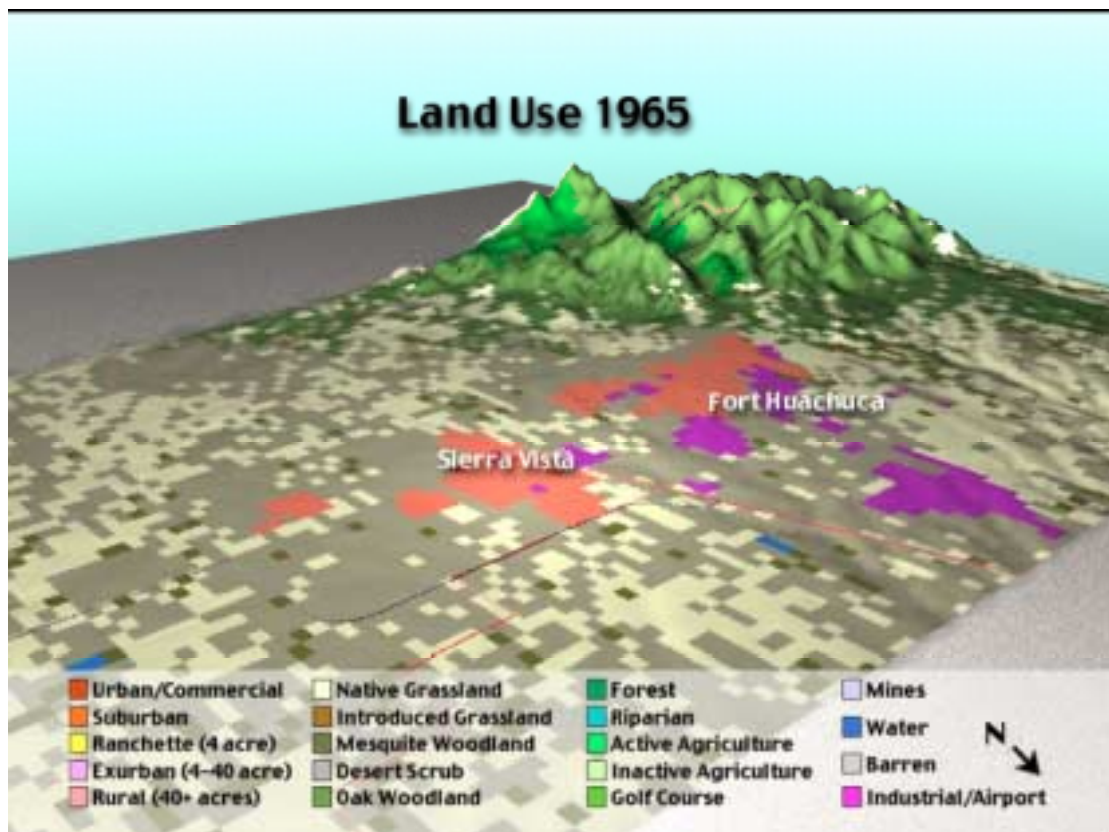


Figure 10. Sierra Vista land use classification 1965, looking southwest.

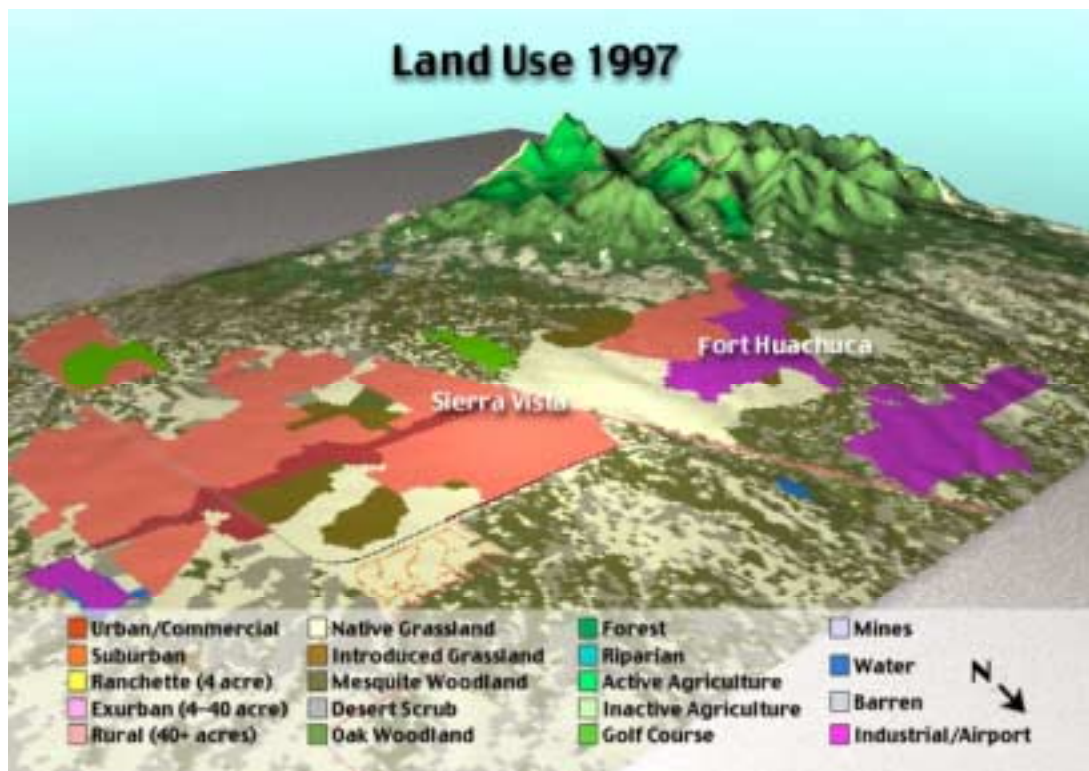


Figure 11. Sierra Vista land use classification 1997, looking southwest.

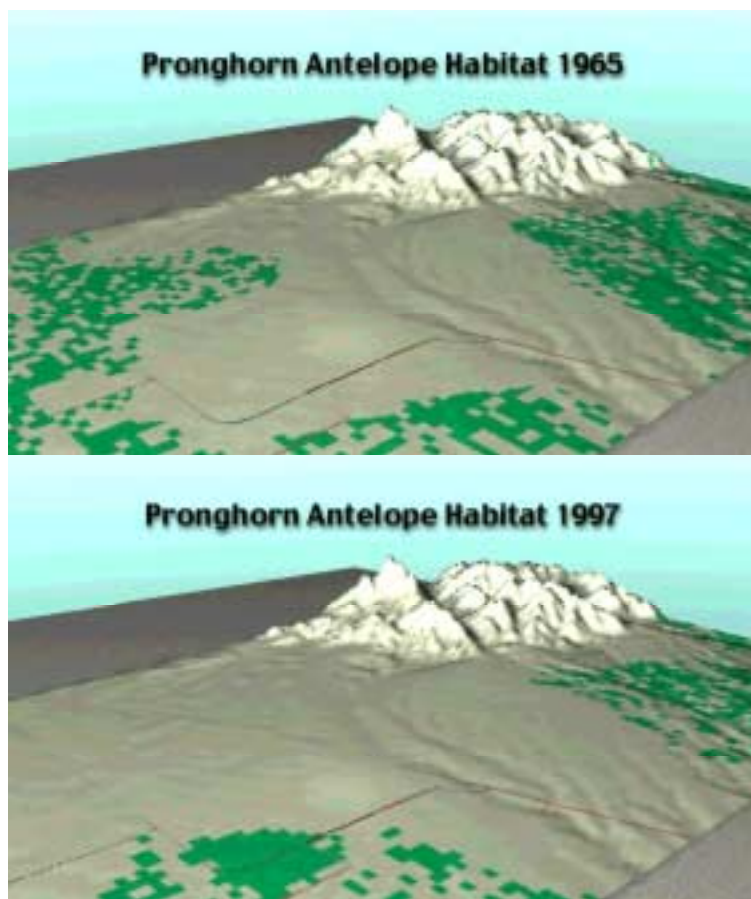


Figure 12. Pronghorn potential habitat, 1965 and 1997.

Conclusion. In addition to quantitative scientific use, Corona imagery can play a valuable role in generating visualizations of land use change. For this purpose, Corona imagery is significantly easier to use than historic aerial photography because of its broad extent and relatively even exposure.

Draping historic Corona imagery over a terrain model and dissolving back and forth to current orthophotography can be used to generate land use change visualizations that are readily understood by a nontechnical audience and therefore can provide impact to the point being explained.

Application Area: Erosion and Identifying Land Carrying Capacity for Military Usage

Installation location used. Fort Story, VA

Description of need for this analysis. Changes in wetlands (dredging or filling) requires a 404 Permit from the Corps of Engineers.* Preservation of training areas, in this case of the shore for Logistics Over the Shore (LOTS) training, allows continuation of the military training mission. Therefore, identification of changes in wetlands and shoreline configuration are important. Fort Story lies on a prominence at the mouth of Chesapeake Bay. It contains many wetlands and is the only location in the United States where LOTS training is carried out.

Comparison between candidate areas on the installation with similar locations off installation will be made. The question to be answered is, "Can we identify a greater amount of wetland area now as opposed to that which existed in the 1960s?" If so, this might relieve some of the wetland restrictions that the installation is currently experiencing.

General description of procedure. One Corona image was rectified to a DOQQ file. Because the disk space required to rectify the entire image was large, the most relevant area for investigation was extracted by clipping. The bounding box for the clipping process was derived from an approximation of the area covered by the DOQQ. The road network, the prominent lighthouse by the bay, and corners of buildings (all clearly visible) provided good GCPs. The resampling procedure applied to this data set was the Nearest Neighbor method.

Imagery resources required. One December 1963 Corona image was scanned. A DOQQ dated April 1997 was used as a base for the main processing and analysis. The DOQQ digital image was orthorectified, with a resolution of 1 meter, and consisted of features that may be omitted or generalized on other maps. An 8- by 8-meter pixel tiff-formatted image, which was extracted from a Color InfraRed (CIR) digital orthophoto, served as a guide to view the study area. The image was photographed on 9 April 1990 by the National Aerial Photography Program and is available in digitized form from the USGS DOQ Program. A DRG file (from the 1963 7.5-minute Quad map - Figure 13) served as a guide.

* Courts have found that wetlands are included within the description of "navigable waters of the United States" as defined by the Clean Water Act, Amended.

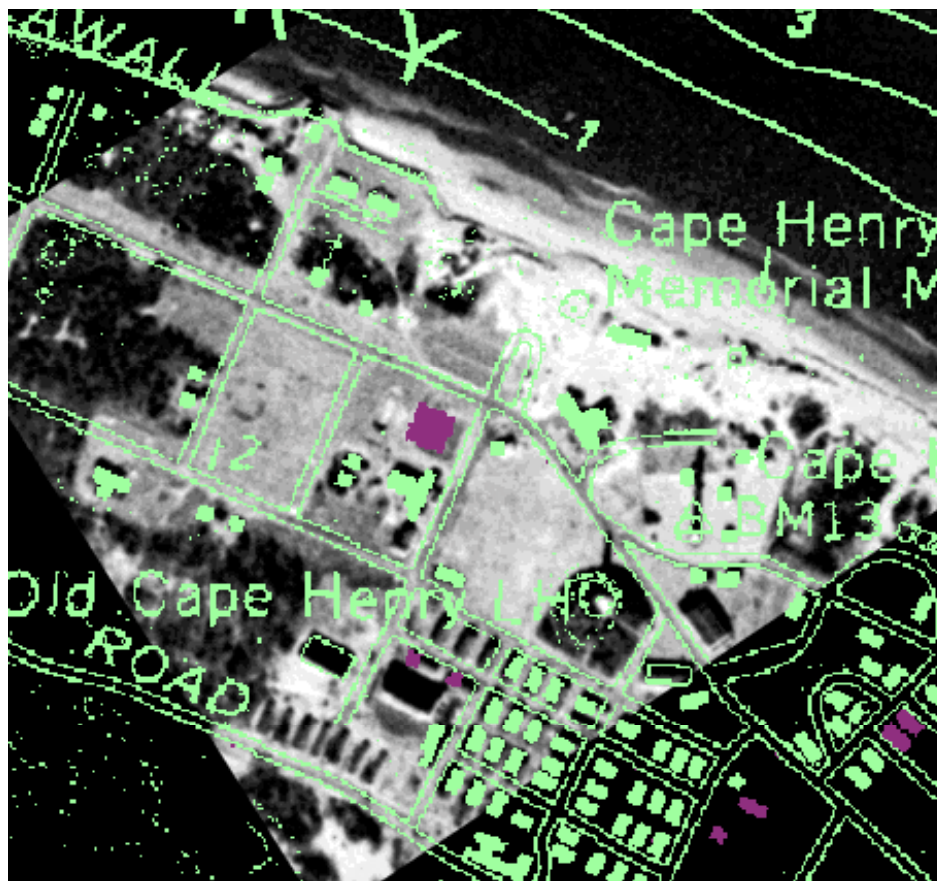


Figure 13. Georeferenced micro-videograph of Light House area (center, lower left) with selectively transparent DRG overlay.

Specific procedure.

1. **Preprocessing:**

Scan Corona filmstrip at 5000 dpi:

Fort_a.img to fort_a_r_36tif.img

Georeferencing:

RMS: 40.85 for Corona transformation to UTM (DATUM/ZONE) based on
DRG 36076h17.tif

GCP: 40 for Corona transformation to UTM (DATUM/ZONE) based on DRG
36076h17.tif

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: none

Nearest Neighbor resampling Method

2. **Clipping:** The Corona image was clipped to the CIR DOQQ. An AOI was defined by the selection of the coordinate corners from the DOQQ image. With a precise definition of these points, the AOI file was saved for future processing. The Corona image was then clipped based on the defined AOI file.

3. **AOI Selection:** The boundaries of the target areas were selected using the AOI function of ERDAS Imagine 8.4. Spectral limitations were found:

- water bodies and wetlands would be confused
- shoreline would be confused with development, waves, and bare land.

AOIs were visually selected for the shoreline inside and outside the installation. Wetland areas were selected inside the installation.

Result. For this study, the area within the image was analyzed as one of three classes: Fort Story Military Installation, State park or State-owned lands, and private lands. The boundary for the installation was based on the DRGs.

A visual analysis between the two images revealed that the environment when the DOQQ was taken was wetter than that exhibited in the Corona image. Figures 14, 15, and 16 show clear evidence that the area experienced recent heavy precipitation in comparison to the Corona image; the environment was wetter. This difference is possibly due to a seasonal difference (approximate 4 months) between the dates of the images.

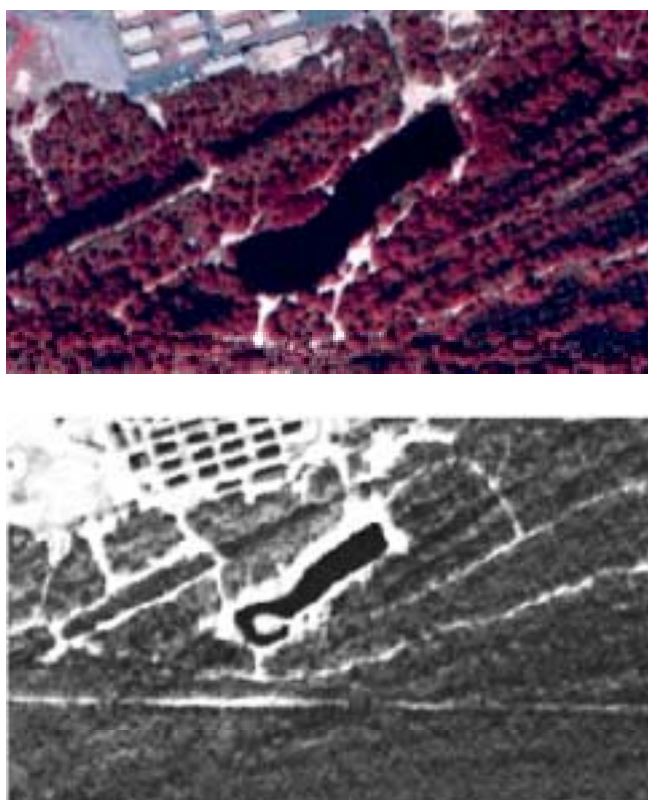


Figure 14. Pond water level changes.

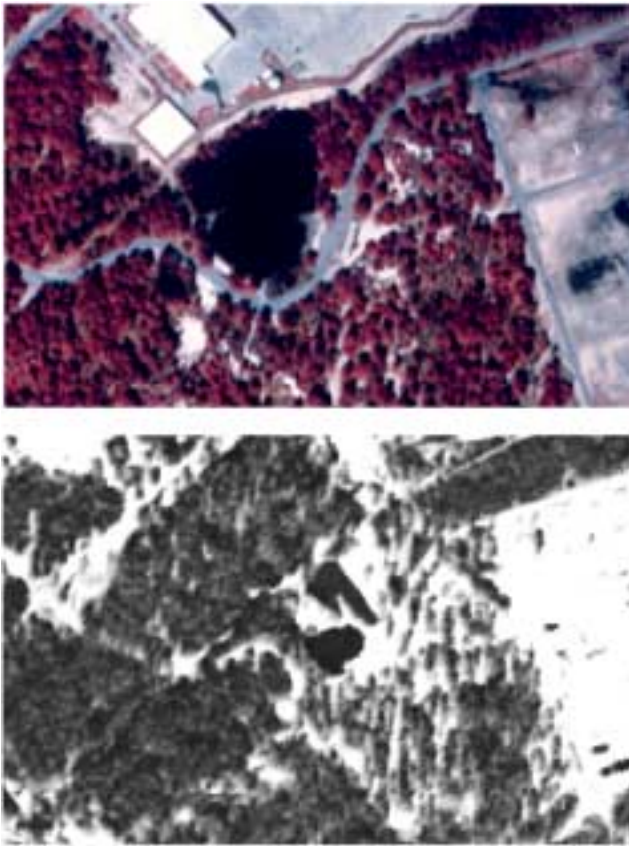


Figure 15. Additional pond water level changes.



Figure 16. Standing water locations (puddles/ponds depicted in the dark tone).

Figure 17 shows that streams were dry and streambeds exposed. Dried streambeds do not appear in the State-owned wetlands; therefore dry streams that exist within the installation are most likely due to different management styles.

Figure 17 shows the shoreline area defined in the Corona and CIR DOQQ images. The AOI on the right (east) represents the shoreline for the installation, while the AOI on the left (west) represents the shoreline for the private ownership. Figure 18 shows that the distance to the shoreline is shorter in the Corona image and longer in the CIR DOQQ image. Figure 19 shows that the distance to the shoreline is longer in the Corona image and shorter in the CIR DOQQ image. In fact the western shoreline is consistently longer in the CIR DOQQ, while the eastern shoreline is consistently shorter in the same CIR DOQQ image. This is an indication of a shift in the shoreline.

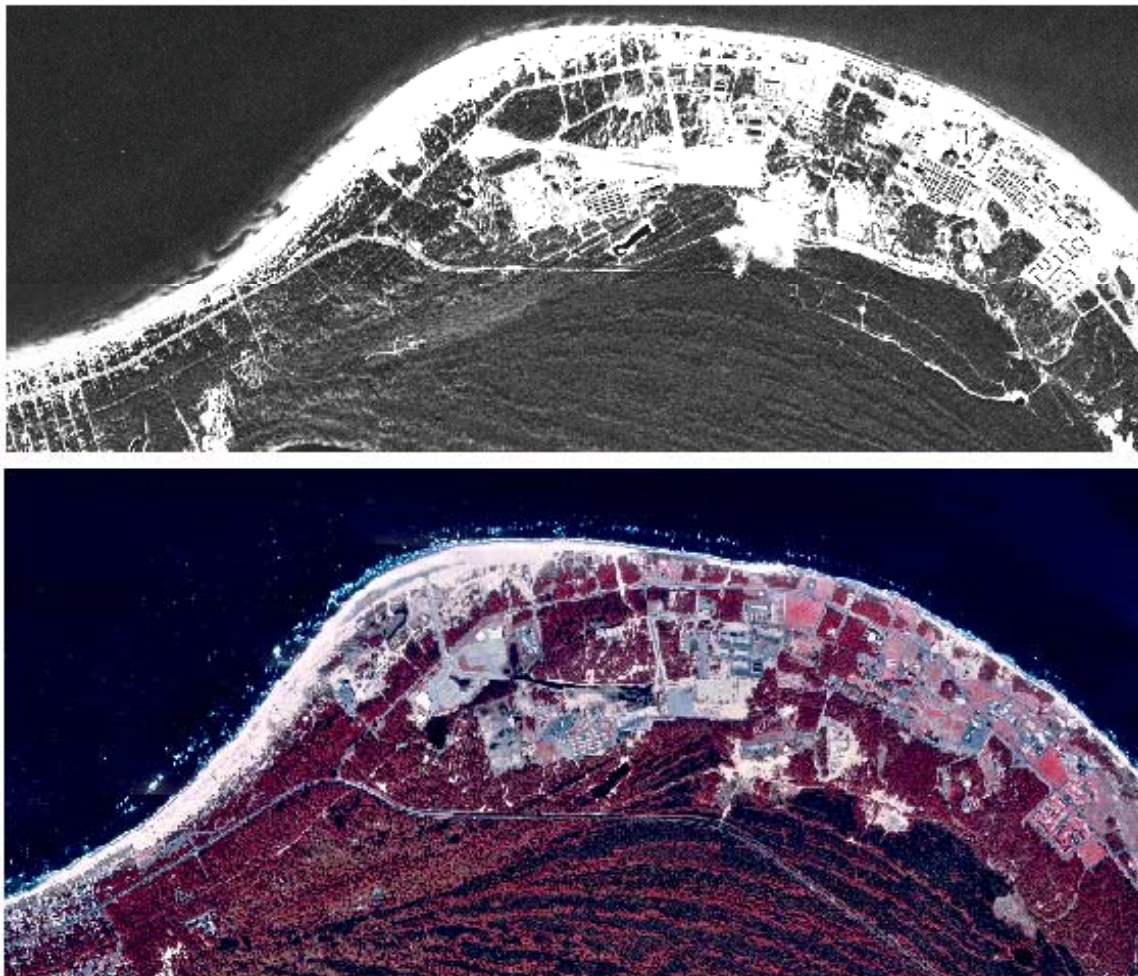


Figure 17. Overview of shoreline location/study area – Corona image and comparison CIR DOQQ.

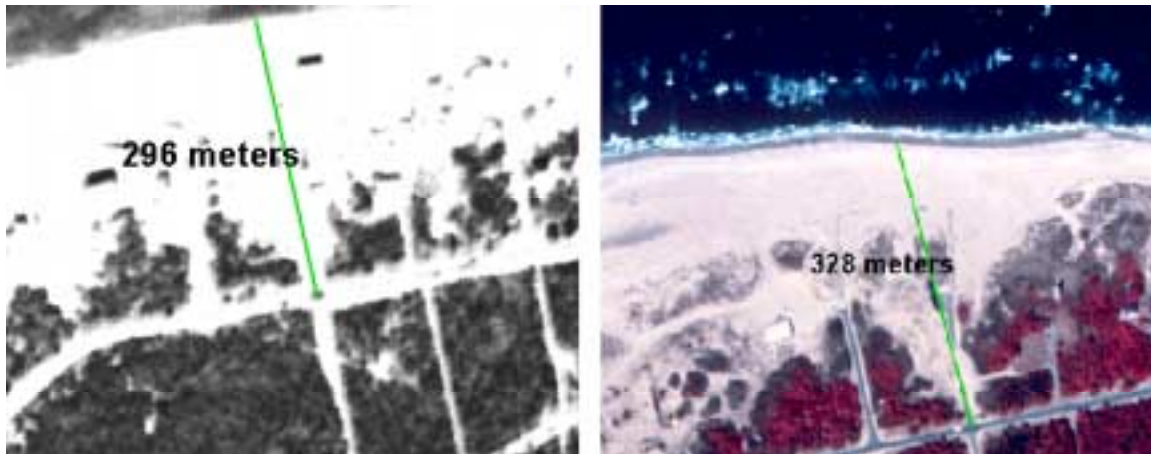


Figure 18. Shoreline distances.

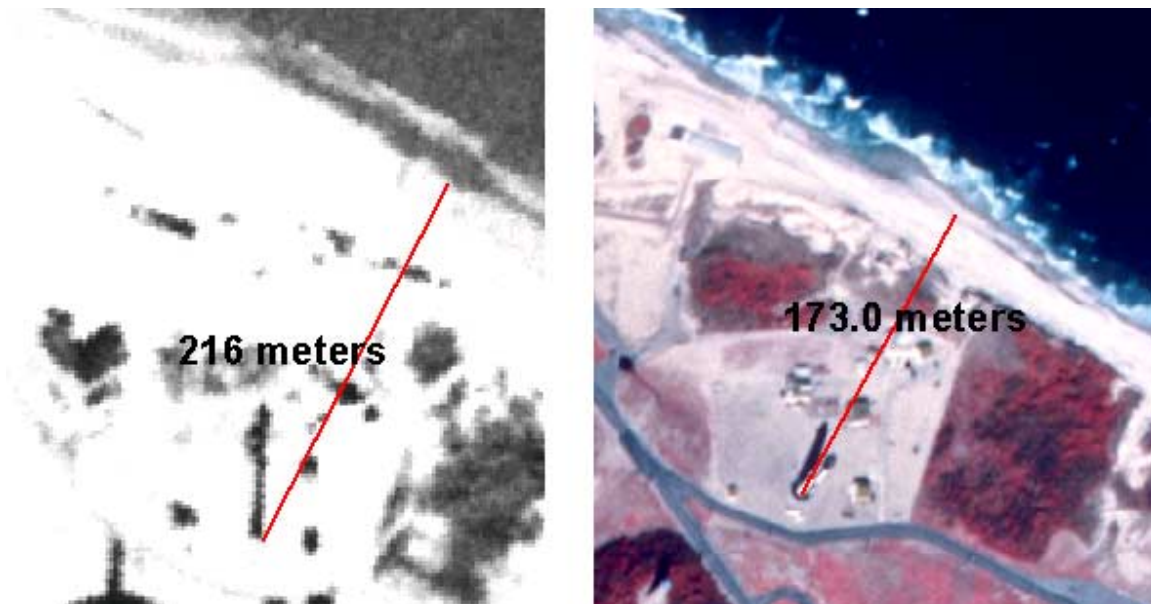


Figure 19. Additional shoreline distances.

Figure 20 (top) shows dried exposed streambeds. Dried streambeds do not appear in the State-owned wetlands; therefore, these dry streams, which occurred inside the installation, are most likely due to a different set of land management practices. These same streambeds as displayed in Figure 20 (bottom) clearly show substantial vegetation recovery in the 1994 DOQQ. Vegetation recovery is more likely to have occurred due to a constant water supply. In fact, on the State-owned wetlands where water flows move freely, similar vegetation patterns are found in both images.

Comparison of Figure 20 (top and bottom) suggests change has occurred in both directions. The top left circles show two areas that have changed from wetlands to developed area. The lower right left circles show two areas that have changed from developed or exposed soils to water bodies.

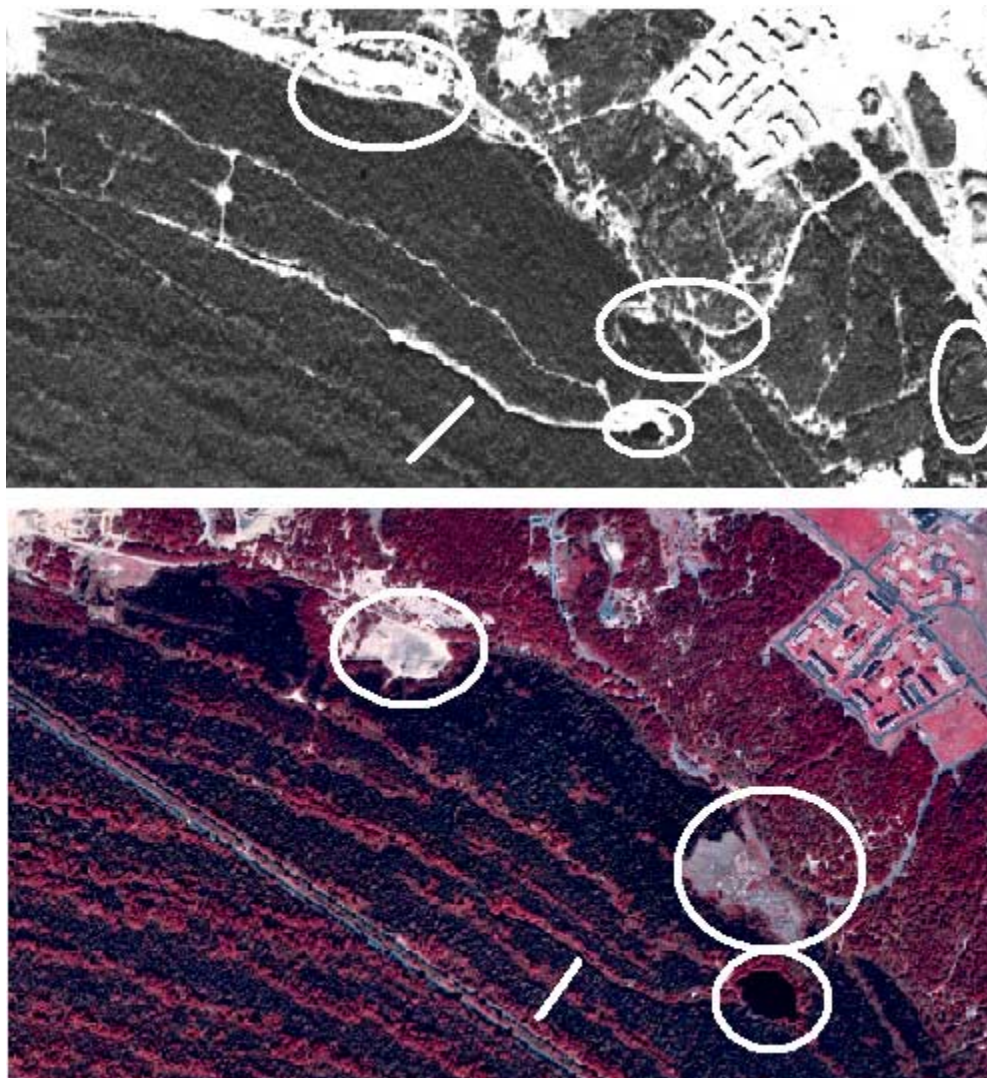


Figure 20. Wetland changes (stream channels and ponds).

Figure 21 displays a similar wetland area within the installation as Corona and color infrared DOQQ images. The wetlands location on the installation and on public land shows development in both locations (Figures 22 and 23), while the wetlands in the State-owned area remained the same.

Table 5 displays the areas for installation's shoreline, private shoreline, and installation's wetland. These areas as shown in Figures 17 and 21 are based on the AOIs selected by visual analysis.

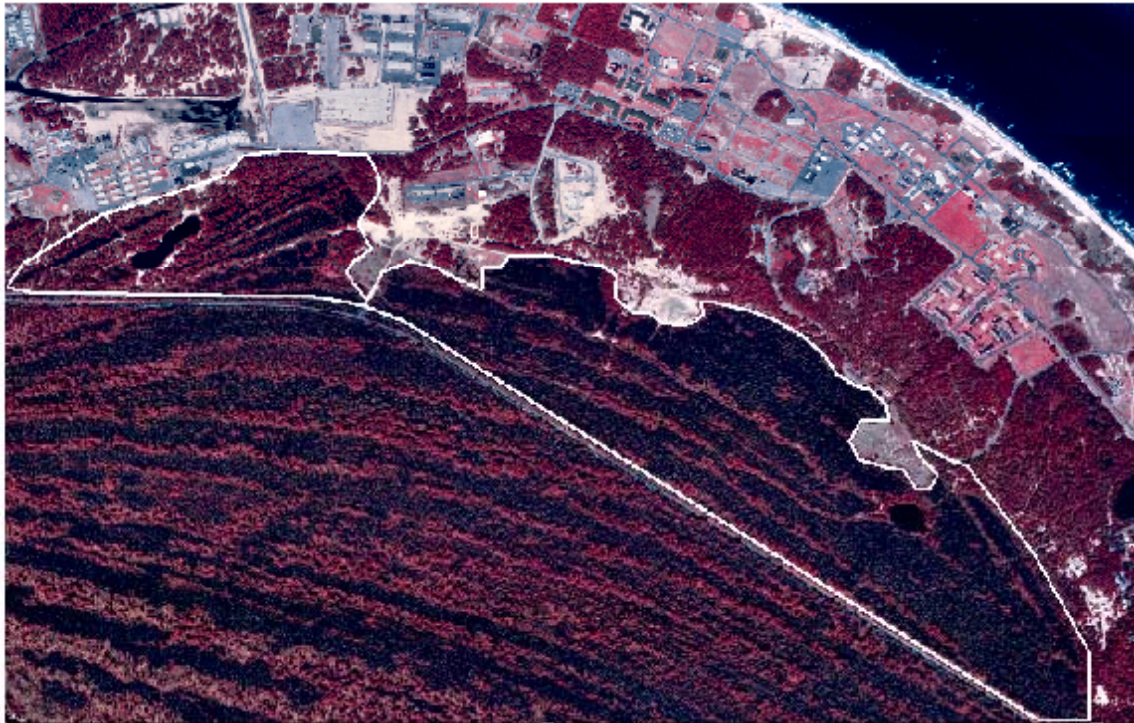
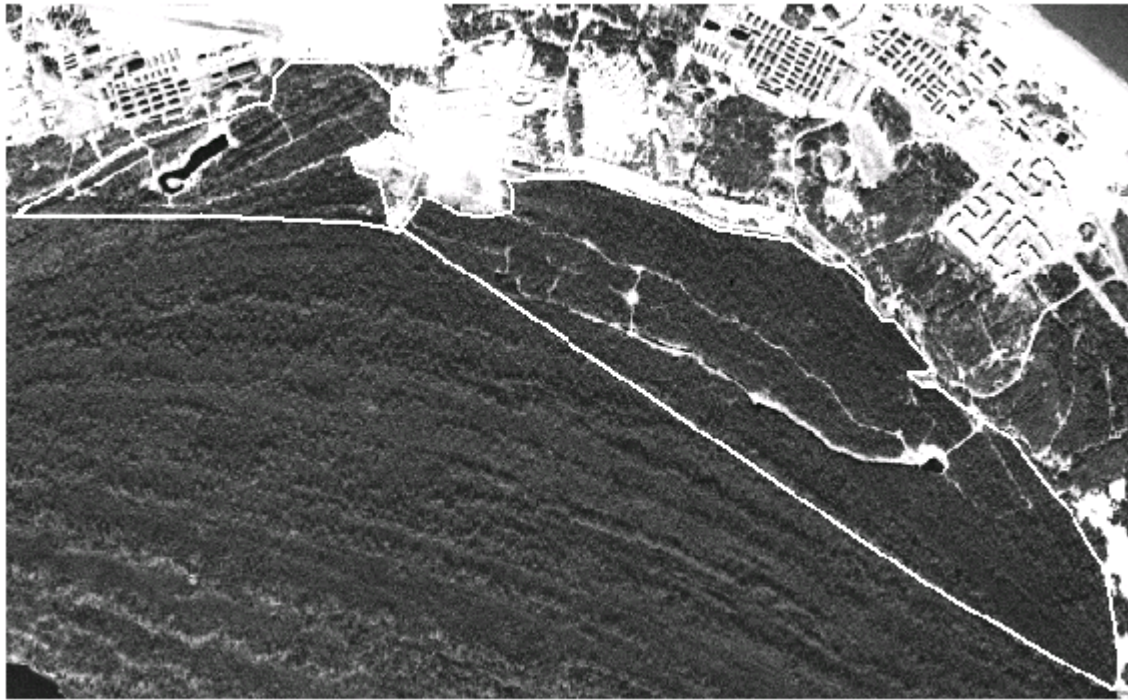


Figure 21. Wetland location – Corona image and comparison DOQQ.



Figure 22. Development areas outside military lands.



Figure 23. Development areas inside military lands.

Table 5. Installation and private shoreline and installation wetland.

Feature of Study	Corona Image	CIR DOQQ	Percent Change
Installation's Shoreline	672,652.69 sq. m	769,864.99 sq. m	14.45%
Private Shoreline	253,655.80 sq. m	286,561.43 sq. m	12.97%
Installation's Wetlands	1,367,232.27 sq. m	1,355,151.22 sq. m	-0.9%

Conclusion. The water level of the ponds increased in the DOQQ. This is likely caused by recent precipitation and the seasonal change.

Based on these images, the overall shoreline area has increased in both the installation and private lands. The western side of the shoreline has increased significantly, while the eastern side has decreased. Due to tides, seasons, and ocean

ocean currents, these results must be investigated further. In this case, it is important that imagery be used in which the season and tides are as comparable as possible.

The wetlands on the installation exhibited areas of wetland recovery and even a slight increase in the area of the wetlands. State-owned lands did not show wetland change. The wetland area in the two images shows some decrease in area both inside and outside the installation.

As demonstrated by this study, the Corona image provides valuable historical information of the land cover type and changes in land use. Not only has the image documented land use differences in a specific area, but also probably shows differences in land management practices based on ownership. Shoreline boundaries are difficult to determine due to the inability to distinguish waves from beach due to the panchromatic nature of the Corona imagery. As a result, it is recommended that the Corona imagery be inspected visually rather than automatically. Though automated classification methods are not recommended, they can be used to limited extent if preprocessed with AOIs to filter out unwanted or complicating features.

Application Area: Forestry Management - Burn Patterns

Installation location used. Fort Huachuca, AZ

Description of need for this analysis. Historic fire burn patterns can suggest to a fire manager how long it has been since the ground fuel has been cleared from an area. Also, the regeneration of a burn area increases and changes habitats for wildlife during the regeneration process to climax vegetation state. Fort Huachuca has good records of burns only as far back as the early 1970s. In this arid region, the forested areas are located at the higher elevations of the Huachuca Mountains. It would be useful to identify burn patterns from the 1960s.

General description of procedure. First, candidate burned areas were selected based on the Corona image. Second, to verify the location of burned areas, a visual comparison between the Corona and TM images was completed. Third, a supervised classification of the TM image was conducted to determine the potential location of other burned areas. To carry out these steps, four Corona images were rectified to a Landsat TM image. The Corona images from three adjacent films were scanned, georeferenced, and tiled to cover the entire installation. The dense road network with a number of road intersections made it possible to acquire a number of GCPs. The resampling procedure applied to this data set was the Nearest Neighbor resampling method.

Imagery resources required. Four Corona images dated 1 March 1965 were used in conjunction with a Landsat TM image dated 8 June 1997. These four Corona films were scanned to cover most of the installation, though only two images were required for this particular analysis. During the scanning process, the dynamic gray-scale range held by the film became limited to 256 levels. In the dark forested areas targeted in this analysis, most of the information resided in only a few levels. The scanning process can result in the loss of value in the needed information. To overcome this, the AOI only was rescanned to emphasize the information in the forested areas. This new AOI in the southern portion of Fort Huachuca (called Garden Canyon) was clipped to a workable size. The boundary data was in Arc coverage format, used in ERDAS Imagine version 8.4.

Specific procedure.

1. Preprocessing:

Scan Corona filmstrip at 5000 dpi

hua_15.img to hua_15_rtm.img

RMS: 711.19 for Corona transformation to UTM (DATUM/ZONE) based on
TM

GCP: 52 for Corona transformation to UTM (DATUM/ZONE) based on TM

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: none

Nearest Neighbor resampling method

hua_16.img to hua_16_reg.img

RMS: 867.52 for Corona transformation to UTM (DATUM/ZONE) based on TM

GCP: 50 for Corona transformation to UTM (DATUM/ZONE) based on TM

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: none

Nearest Neighbor resampling method

Hua65_15_r_v3_gardencany.img to garden_cany_rtm.img

RMS: 355.05 for Corona transformation to UTM (DATUM/ZONE) based on TM

GCP: 24 for Corona transformation to UTM (DATUM/ZONE) based on TM

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: none

Nearest Neighbor resampling method

2. **Clipping:** The Corona and TM images were clipped to include land areas that were high in elevation. Figure 24 shows the images with the boundary of Fort Huachuca.

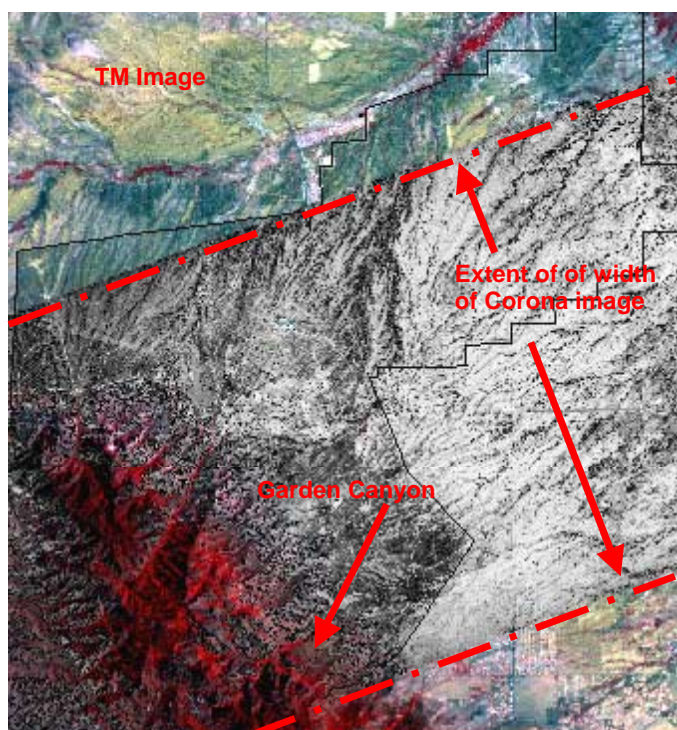


Figure 24. Administrative boundary for Fort Huachuca; Landsat TM and Corona image overlay.

3. **Spectral Enhancements:** The Landsat TM image was spectrally processed for Principal Component 2 (PC2 is used for Vegetation Analysis) and Vegetation Index (Band 4 – Band 3).
4. **Stacking:** The Landsat TM model layers were then merged together with the original TM image using the “Stacking” function in ERDAS Imagine 8.4.
5. **Visual Analysis of Burn Locations:** Because no records existed of burn locations prior to 1972, this analysis determined the most likely locations for the target using different information sources (Figure 25).

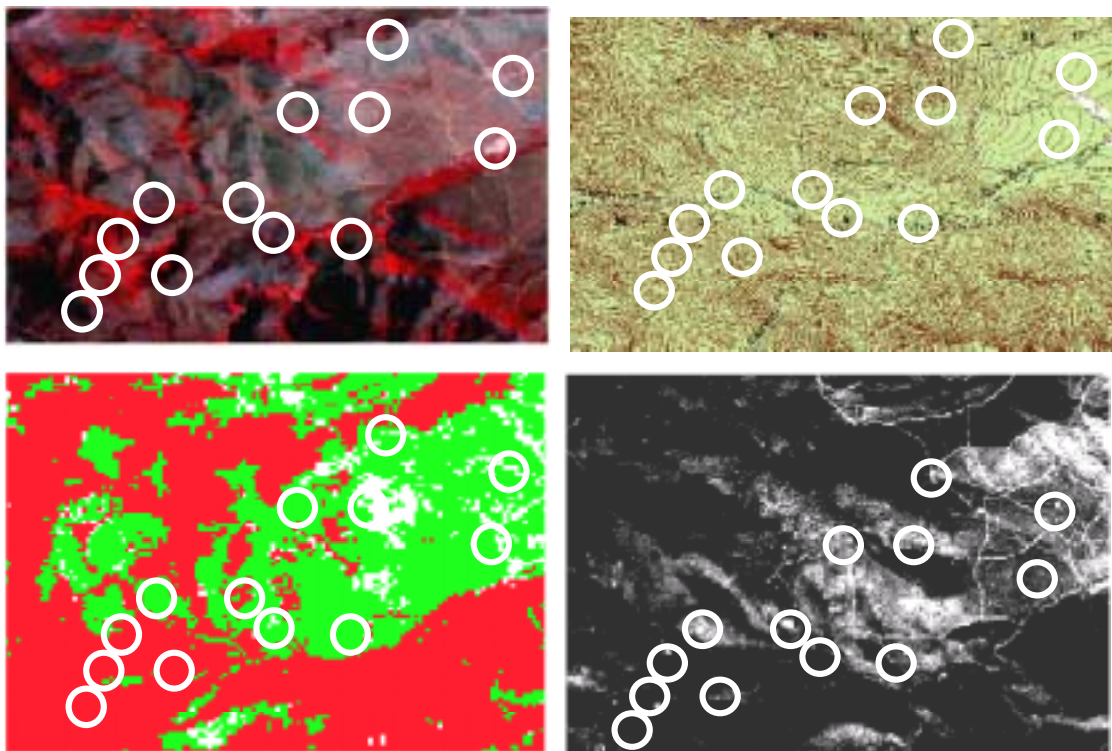


Figure 25. Most likely locations of burns; Landsat TM (upper left), Digital Raster Graphics file (upper right), classified TM image (lower left), and Corona image with low dynamic range (lower right).

6. **Supervised Classification:** Samples of the suspected burned areas are collected on the Corona image as shown in Figure 25 (lower right). The samples are collected using the “Seed” function using a Spectral Euclidean Distance of 10.00.

Due to the differences in the terrain and ecosystems of the 14 samples (total 697 pixels), 8 samples are removed from the original, leaving 6 samples (total 323 pixels) that fell within the mountain terrain.

Two supervised classifications were performed on the TM image: the spectral enhanced PC2 and vegetation layers. The first supervised classification included all 14 samples, while the second classification included only the 6 samples that

fell within the mountain terrain. Both supervised classifications had the following rules applied: Parallelepiped for Nonparametric Rule, Parametric rule for Overlap Rule, Unclassified Rule for Unclassified Pixels, and Maximum Likelihood or the Parametric Rule.

Result. A visual comparison of the TM image to the Corona image showed no pattern of the burned areas.

A supervised classification was performed to determine if a pattern could be found. The first supervised classification, which included all 14 samples, showed no burned area patterns as shown in Figure 26. The second supervised classification, which included 6 samples located in the mountain terrain only, also exhibited no burned area patterns (Figure 27).



Figure 26. Supervised classification (14 samples).



Figure 27. Supervised classification mountain area only (6 samples).

Conclusion. Though Corona images potentially provide a good historical record of areas where fires are likely to have occurred and they may serve as a guide to locating potential burned areas, due to their panchromatic nature, determining the difference between burned, forest, and bare areas was difficult. The resultant statistical error level is too high to have confidence in the use of a supervised classification to locate other burned areas in the Corona image. Additional information sources had to be used to verify suspected burned areas. However, the available TM image could not provide the additional verification information. The TM data is limited because:

- Approximately 30 years had passed between the dates of the TM and the Corona images in this study. Although the vegetation would not be expected to fully recover in 30 years, due to the slow growth in the high elevation and arid climate, it was hoped that the vegetation recovery would be sufficiently slow to show identifiable spectral returns in the vegetation signatures in the TM image. This was not the case.
- The spatial resolution of the TM image (28.5 m) is too gross. Figures 28 and 29 display a white polygon showing the area of the pixels for one of the samples used. The Corona image contains a large number of the pixels compared with the TM image. Pure spectral pixels could not be identified due to this pixel resolution. For this reason, a high incidence of spectral confusion and misclassification can be expected. Figures 26 and 27 illustrate this confusion.



Figure 28. TM (left) and Corona (right): pixel samples (small area – 246.5 meters).

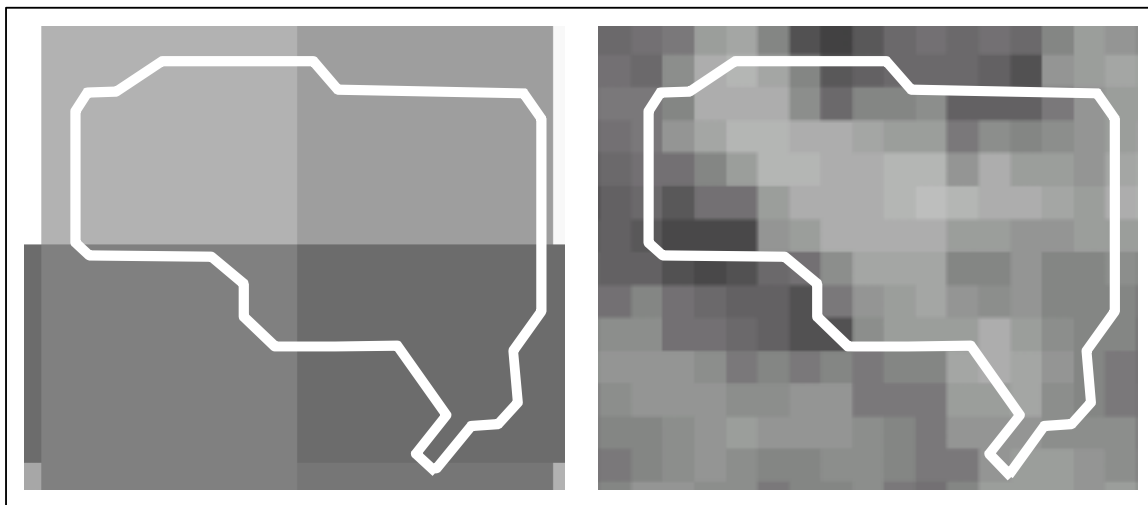


Figure 29. TM (left) and Corona (right) pixel samples (large area – 1,342.5 meters).

This type of analysis would be more productive if it was performed using imagery that was acquired within a few years after the areas have been burned. Unfortunately, the first Landsat imagery available is from 1972, but it comes

with even grosser resolution (the MSS imagery was at 80 meters per pixel), so the classifications using it can be expected to carry even higher confusion statistics. To use Landsat imagery as a verification resource for locating the burned areas, the burn areas should be larger. At best, only large burns are likely to be identified with the Corona imagery. If they were large burns, it becomes more likely that records of their location and existence will be available. Therefore, Corona imagery is not recommended as a practical resource to identify old burn locations.

Application Area: Habitat Changes

Installation location used. Fort Huachuca, AZ

Description of need for this analysis. Wildlife managers on installations need to identify the direction of habitat trajectories (direction of change of the habitat over time) from the change in vegetation cover over time.

General description of procedure. Please refer to Land Use Change Investigations at Fort Huachuca (page 32) section for initial discussion. Roadless areas were extracted. With professional input, habitat characteristics were identified with the assistance of much grosser resolution archival MSS imagery. Comparison was made to more recent (1997) imagery.

Imagery resources required. 1965 Corona image, 1973 Landsat MSS image, 1997 land use classified image.

Specific procedure. To get a sense of the ecological impact of change in roadless areas, the potential habitat for the pronghorn antelope was modeled. This species avoids both roads and human development, and has known habitat requirements and home range sizes (Clemente et al. 1995). Note that this model (detailed in Basset 2000) considers only direct impact of habitat due to land use conversion and is based on potential, not actual, habitat (Figure 30).

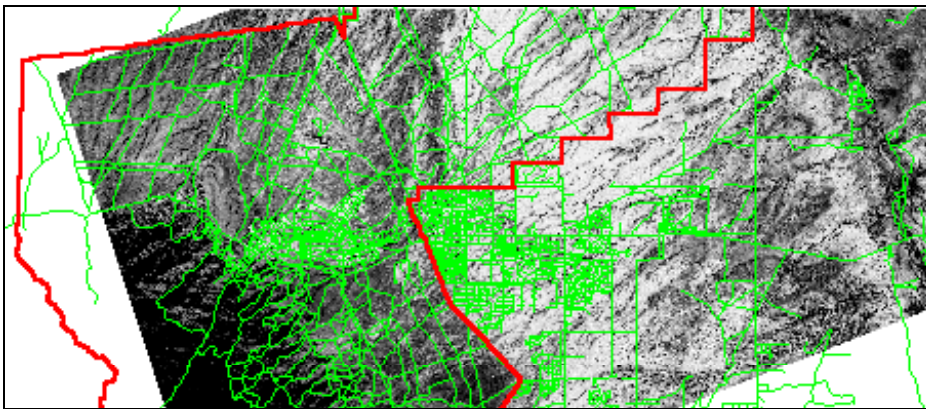


Figure 30. Area of study, Corona film, Fort Huachuca boundary (red).

Because it was not possible to classify grasslands directly from the 1965 Corona imagery, habitat was estimated by underlaying a 1973 Landsat MSS classification (Kepner 1999) beneath roads and built features classified from Corona. Unknown areas (such as those with cloud cover) were interpolated based on their surrounding values, using the ArcInfo grid “nibble” command. The Landsat classification was not available at its full resolution at the time of analysis so a

170-m resolution version of the classification was used. Because this is a significantly lower resolution than the other data sources, it is likely that some vegetation changes are simply a consequence of scale differences rather than of land use change.

Also, in a recent accuracy assessment of the original classification, Kepner (1999) reports a data registration error that is visible in the analysis.

Result. Potential Pronghorn habitat in the roadless areas, decreased about 2.5 times faster than it increased in the over 30-year coverage of this analysis (Tables 3 and 4 in the section Land Use Change Investigations for Fort Huachuca [page 32] and Figure 31).

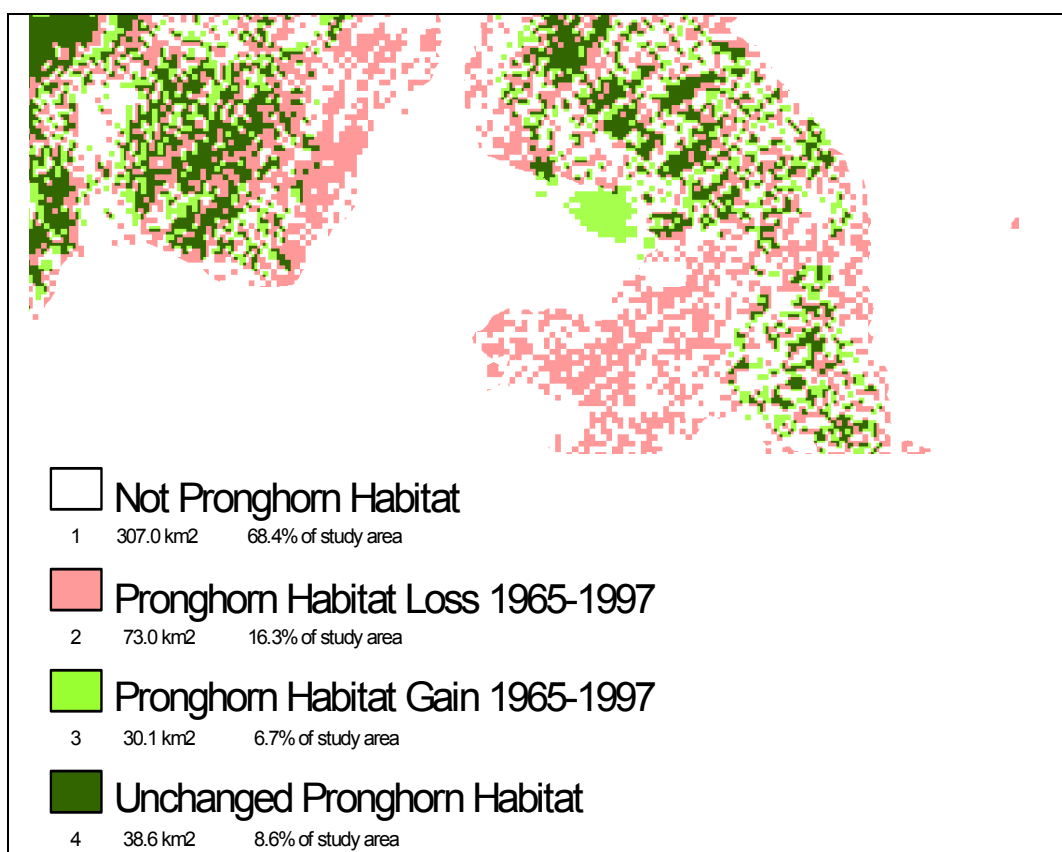


Figure 31. Changes in Pronghorn habitat between 1965 and 1997.

Conclusion. In this example, combining the detail of the Corona imagery with the spectral information in a Landsat MSS image is a useful means of developing habitat extant in the 1960s. This example also illustrates the usefulness of professional input in the development of a model as opposed to a simple computer evaluation. The high resolution of the Corona image in this analysis was hampered by the lack of an MSS image at the original resolution of 60 meters. This can be overcome given more time.

Application Area: Aquatic Habitat Monitoring and Mapping

Installation location used. San Diego Bay, CA (Naval Facilities Engineering Command, Southwest Division, San Diego, CA)

Description of need for this analysis. The Naval Facilities Engineering Command (NAVFAC) has a requirement under a number of Federal laws and regulations and under Navy regulations to manage environmental quality on lands and waters under Navy control and to assure that Navy activities elsewhere are conducted in accordance with all laws and regulations. NAVFAC must also manage Navy lands and waters to meet Navy mission objectives for sustainable training use.

NAVFAC, Southwest Division, San Diego, CA, is currently studying, monitoring, and mapping the extent of eelgrass, a submerged aquatic plant, in San Diego Bay. The purpose is to determine the factors affecting this important aquatic vegetation and to assess the effects of Navy activities in San Diego Bay on the species. NAVFAC currently has several special study areas for eelgrass that are being investigated by various means.

General description of procedure. New classified images were acquired and analyzed by NAVFAC environmental personnel to determine the ability to map eelgrass distribution and to determine eelgrass condition at several study plots in San Diego Bay.

Imagery resources required. High-resolution classified images.

Results. Classified images were successfully obtained and used by NAVFAC personnel.

Conclusion. Analysis of the classified imagery indicated that this resource could provide very useful data to supplement other unclassified data sources for monitoring and mapping eelgrass in San Diego Bay.

Application Area: Endangered Species Habitat Monitoring

Installation location used. San Clemente Island, CA (Naval Facilities Engineering Command, Southwest Division, San Diego, CA)

Description of need for this analysis. San Clemente Island (Figure 32), off the coast of southern California is an important Navy training and gunnery area. However, the island is home to several endangered and threatened plants and animals. The Navy must manage the island and adjacent waters for environmental quality in order to meet the mission objective of sustainable training use. The Navy must also manage recovery and maintenance of endangered and threatened species under the provisions of the Endangered Species Act and Navy regulations. However, it is often difficult to conduct adequate on-ground and on-water monitoring and measurement activities needed for proper environmental management because the island is difficult to reach, on-going training activities restrict island access, and the possible presence of unexploded ordnance makes some areas unsafe for on-the-ground activities.



Figure 32. San Clemente Island, CA.

General description of procedure. High-resolution classified images were obtained of the China Canyon area within the Shore Bombardment Area of San Clemente Island. China Canyon contains habitat of the San Clemente Loggerhead Shrike (Figure 33), the most endangered bird in North America. Environmental personnel with appropriate security clearance analyzed the imagery to determine its usefulness as an adequate data source for habitat monitoring.



Figure 33. San Clemente Island Loggerhead Shrike.

Imagery resources required. High-resolution classified images.

Results. Imagery analyzed was determined to be very useful for monitoring shrike habitat in China Canyon.

Conclusion. Classified imagery would greatly help overcome the difficulties and constraints associated with on-ground monitoring of the shrike habitat area and could be useful for other areas on San Clemente Island.

Application Area: Discovery of Disposal Sites

Installation location used. Dugway Proving Ground, UT

Description of need for this analysis. Installation personnel suspect the existence of undocumented disposal sites. They need to know if Corona imagery can be used to identify the potential existence of such sites. Research personnel also wanted to compare the ease and effectiveness of carrying out this type of study in two differing climates: Dugway PG represents an arid location and Fort Eustis, VA (see page 70) represents a humid climate.

General description of procedure. Researchers cut a single strip of film into four sections for scanning and visually inspected the section within the installation boundary. The Corona image and a Landsat TM image were processed using ERDAS Imagine 8.4. The next step was to rectify the Corona image to the referenced Landsat TM image. The resampling procedure applied to this data set was the Nearest Neighbor resampling method. The Dugway data consisted of a series of grids that were key in locating test sites. The grids varied in shape and size from rectangular to triangular to circular (Figure 34). The intersections of these grids were used to locate ground control points, thus facilitating a highly precise georeferenced Corona image. Two ArcInfo coverages were used to define the installation boundary and the road network.

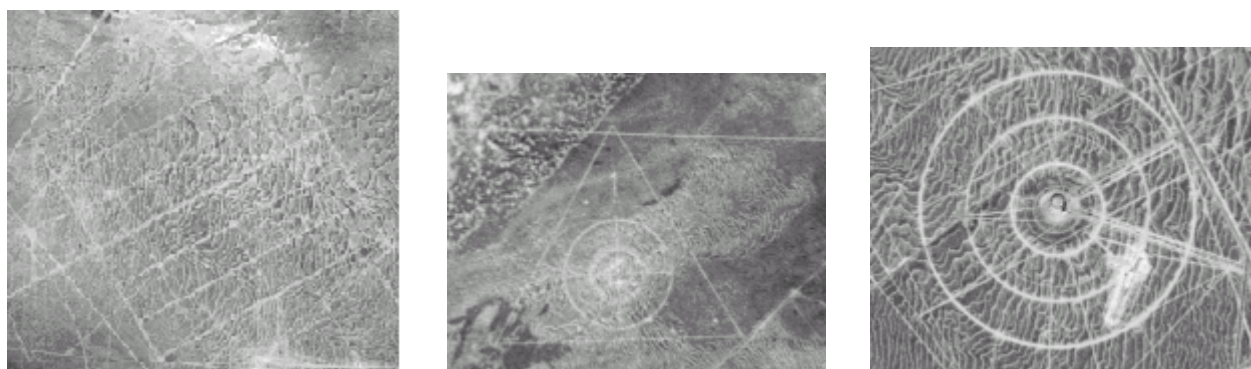


Figure 34. Rectangular, triangular, and circular grids.

Imagery resources required. A Corona image dated December 1969 and a Landsat TM image dated 1992 were used. The coordinate system was the Universal Transverse Mercator (UTM), Clarke 1866 projection system.

Specific procedure.

1. Preprocessing:

Scan Corona filmstrip film at 5000 dpi.

RMS: 866.56 for Corona transformation to UTM (DATUM/ZONE) based on
TM

GCP: 52 for Corona transformation to UTM (DATUM/ZONE) based on TM
Geometric Correction Model: Polynomial Order: Second
Mosaicing Edge Matching Rule: none

2. **Analysis:** Visually, the grid network was the predominant feature within the Dugway PG. The grids were generally found east of the prominent granite ridge, expanding to the north and south of it. The dimensions of these grids and their numbers could be accurately assessed with the 2-meter resolution Corona image. However, they were not clearly visible in the Landsat TM image due to its lower resolution.
3. **Release Areas:** The release areas in the circular grids were identified by their central U-shaped structure; for rectangular grids and other patterns, a characteristic cross or clover leaf shape (Figure 35). These features are not visible on the Landsat TM image.

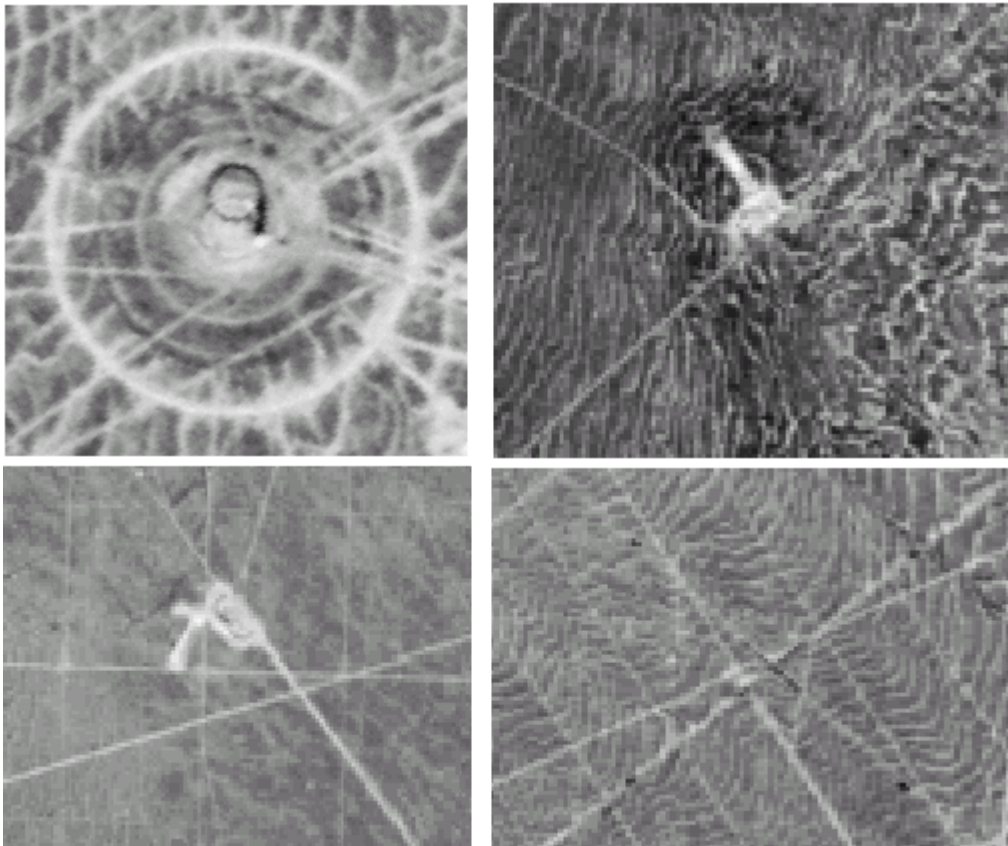


Figure 35. Release areas depicting a variety of structures.

4. **Surface Soil Texture:** In the Corona image, the installation boundary line was prominent. This prominence helped when analyzing the surface soil texture inside and outside the boundary. The relatively coarse nature of the soil within the confines of the Dugway site (Figure 36 [top]) is noticeable compared to the smooth surface soil texture found outside the boundary (Figure 36 [bottom]).

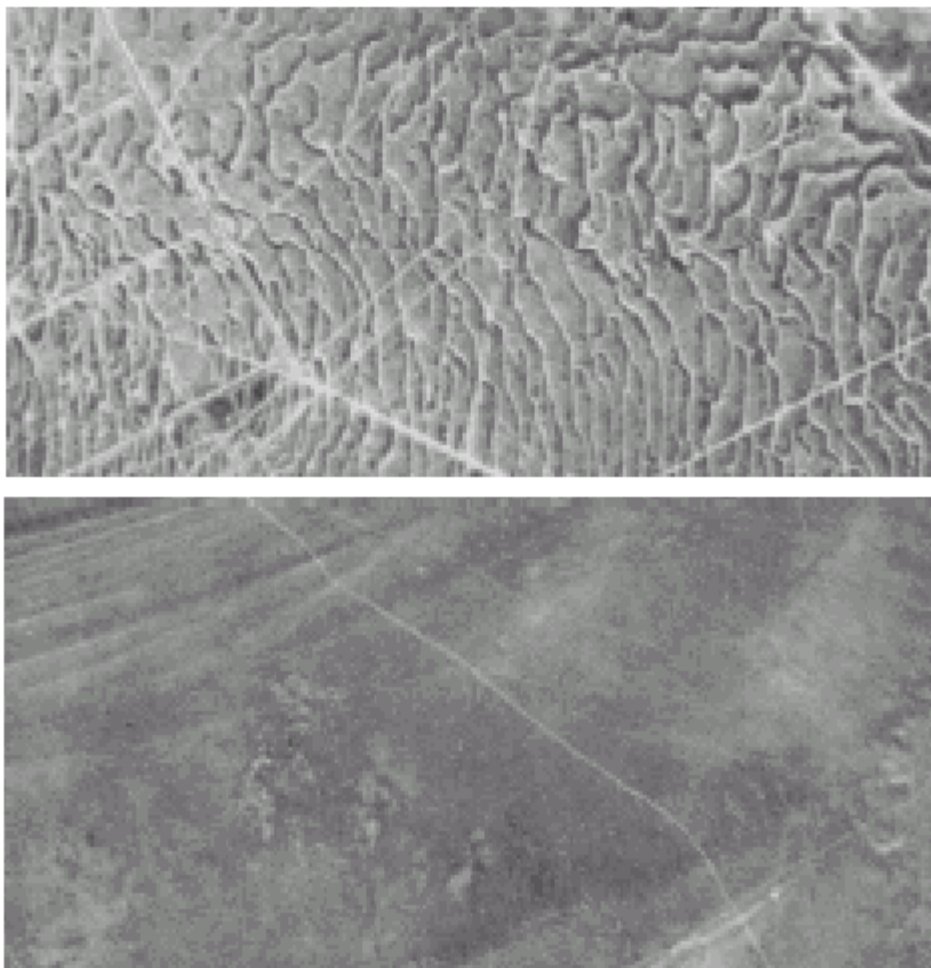


Figure 36. Soil textures inside (coarse) and outside (smooth) the installation boundary.

Given the barren land surface in the Dugway environment and the ability to directly observe the texture of the soil, it seems reasonable to conclude that large amounts of surface material have been transported and dispersed by the wind. These wind-blown deposits can be traced to miniature dunes, as shown in Figure 37 (left). The form of the wind-worked deposits suggests direction of the prevailing wind: roughly North-North-Westerly (NNW).

At several locations, traces of deposition plumes and their direction could be related to adjacent release areas. Deposition residues were found at a distance from the release area shown in Figure 37 (right). Scars and other traces visible on the land suggest that they also come from the release location (Figure 37, right). Similar series of these deposition plumes could be found at various locations within the Proving Ground. Because these features exist only on the Corona images, they afford a unique resource of wind and military testing activity at Dugway PG in the late 1960s.

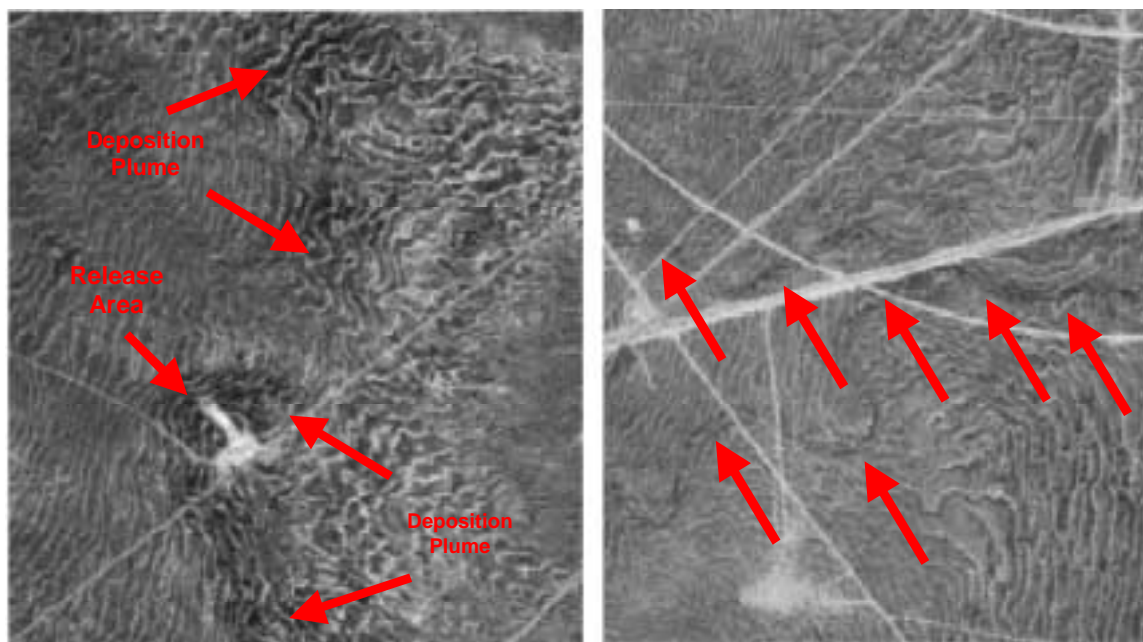


Figure 37. Left: deposition plumes, wind-dispersed deposits; Right: traces of leaching.

5. **Leaching:** There is some evidence of the leaching of the surface or subsurface soil. Similar leaching can result from a stream of radioactive substances being washed through the soil. Though not confirmed in any way, this may be a clue to detecting an area potentially affected by the deposition of hazardous material. The direction of flow could be assessed with the aid of a gradient analysis, used to discover the actual location of these deposits. A candidate stream is conspicuously depicted in Figure 37 (right). It is not portrayed in the corresponding Landsat TM image.

Conclusions. The Corona imagery is capable of tracking and detecting deposits of wind-borne training or hazardous material and can provide a clue to potential unrecorded testing locations. Because these features exist only on the Corona images and cannot be seen even with much later TM imagery, Corona images afford a unique resource of wind and military testing activity during the 1960s at installations in dry climates. However, a spectrally varied image, such as a TM image, is capable of generating signatures in areas where the air-borne deposits are found. Additional information is useful in allowing the detection of incompletely identified objects.

Application Area: Discovery of Disposal Sites

Installation location used. Fort Eustis, VA

Description of need for this analysis. Personnel at Fort Eustis, VA suspect the existence of undocumented disposal sites. They need to know if imagery can be used to identify the potential existence of such sites. Research personnel also wanted to compare the ease and effectiveness of assessing possible disposal sites in two differing climates: Fort Eustis represents a humid/forested location and Dugway Proving Ground, UT (see page 66) represents an arid location.

General description of procedure. To assess the ability of the Corona satellite imagery to detect landfills and other hazardous disposal sites, researchers used a single Corona image and a set of comparison Digital Orthophoto Quarter Quadrangle (DOQQ) files. The Corona image was rectified to a DOQQ. The DOQQ images were overlaid to create a single file. The Corona and the DOQQ covers Mulberry Island, an area where Fort Eustis is located. With the location of training sites and the presence of an intense road network, particularly road intersections (seen in Figure 38), it was possible to acquire a sizeable number of ground control points (GCPs). The resampling procedure applied to this data set was the Nearest Neighbor resampling method.



Figure 38. A general overview – Corona image depicting the location of Fort Eustis military installation.

Imagery resources required. A November 1964 Corona image and a black and white DOQQ dated September 1996 were adopted for the preprocessing and analysis. The DOQQ digital image was orthorectified, with a resolution of 1 meter in a UTM projection. An additional MrSID (Multi-Resolution Seamless Image Database) Portable Image Format mosaic was constructed from a series of tiles to provide an initial view of Mulberry Island.

Specific procedure.

1. Preprocessing:

Scan Corona filmstrip film at 5000 dpi.

RMS: 23.03 for Corona transformation to UTM (DATUM/ZONE) based on DOQQ

GCP: 20 for Corona transformation to UTM (DATUM/ZONE) based on DOQQ

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: none

- 2. Clipping:** The Fort Eustis Corona image clipping was based on the area covered by the reference DOQQ. A boundary polygon was defined in order to enhance the precision of the rectification. The end product was an extract from the Corona image scan line covering the entire Fort Eustis military installation and the surrounding area.
- 3. Analysis:** Fort Eustis is located in Southern Virginia. The James River in the North-North-West and the Warwick River in the East bound it. The topography is generally flat with open sandy soil beaches in the western section along the James River. Generally the military installation consists of dense forest cover and wetlands. There is also a series of inland waterways and channels.

Visual assessment was used to identify landfill, hazardous material, and dump sites. The evaluation of the waste sites initially required an assessment of the vegetation condition and the general land cover. Fort Eustis provided a rough map of potential restoration site locations. This provided the initial source for the investigation.

The dense vegetation seen in the 1964 Corona image served as a key ingredient to detecting the sites (Figure 39, top). In comparison, the vegetative growth is poor in the 1996 DOQQ image (Figure 39, bottom). This type of contrast is useful in identifying the landfill.

At a larger spatial scale other factors considered were:

- Evidence of disturbances
- Low or no vegetation cover
- Change in vegetation distribution.



Figure 39. Comparison location, Corona image (top) and DOQQ (bottom).

An example of change in vegetation distribution is illustrated in Figure 40, where the foliage cover in the Corona image (top) appears more lush than in the DOQQ image (bottom).

Fort Eustis represents a humid/forested installation. We compared the relative difficulty of doing a similar investigation at a site in a drier climate. (See previous section on Dugway for specific investigations.) It proved to be much easier to detect plumes or waste deposits in a drier climate. The arid land is more barren, with little to no vegetation cover, making it easier to trace wind-blown deposits. On the other hand, a coastal site with relatively rich foliage cover like Fort Eustis made it more difficult to detect landfills or waste deposit sites. Further, the abundance of wetlands and the vigor of vegetative growth can more rapidly obscure (or even absorb) traces of the landfills and dumps.

Conclusions. Detailed sequential image series spanning several years are useful in the investigation of landfill operations and waste disposal sites.

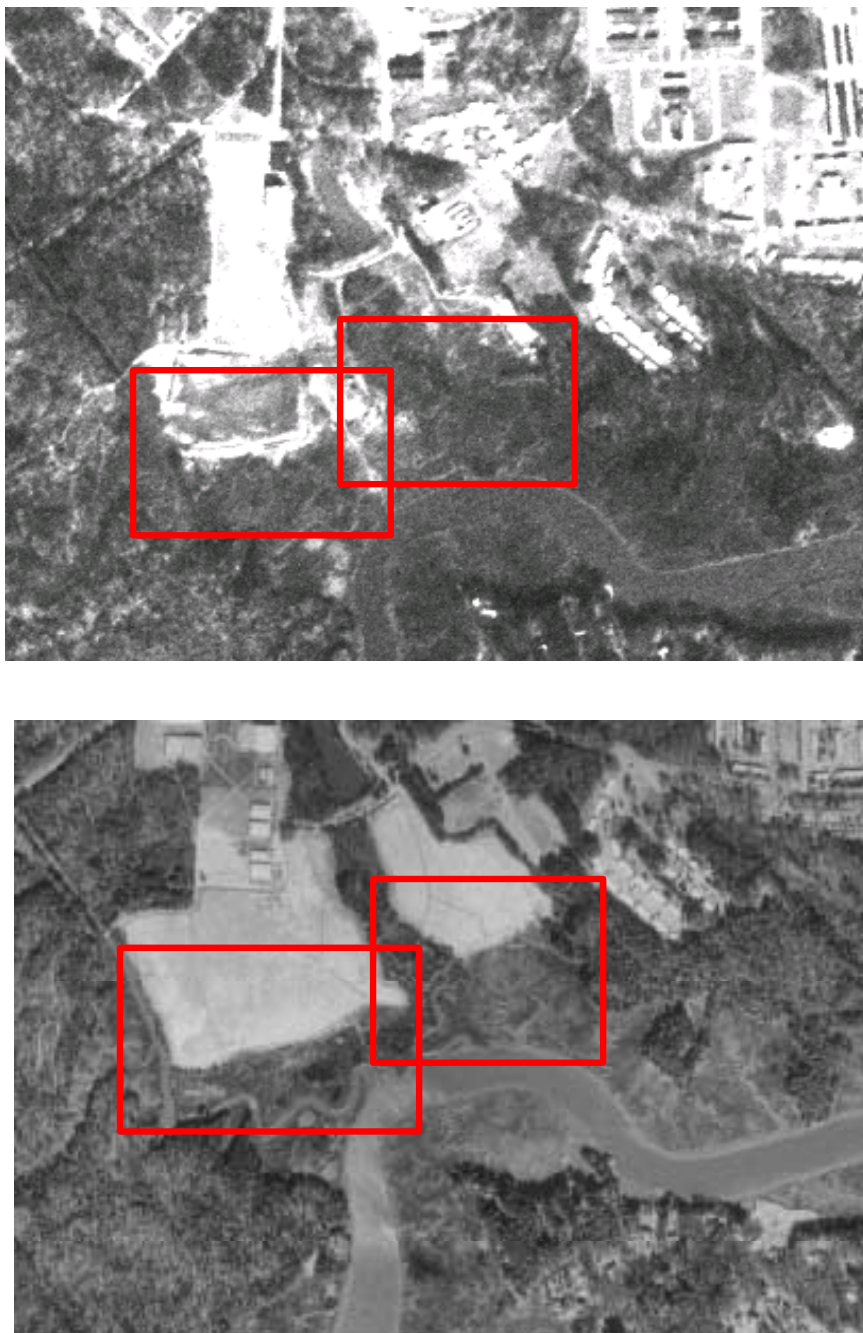


Figure 40. Areas suggesting vegetation loss.

Because of the high resolution offered by the archival Corona imagery and the more recently generated DOQQ images, locations of and spatial coverage of disposal sites can be determined. The analysis could be improved by the addition of a more robust GIS database.

It is easier to carry out this type of application in a drier climate where the absence of vegetation allows the fingerprints from disposal activities to remain more visible through time.

Application Area: Oil Spill Damage in an Estuarine Environment

Installation location used. Roosevelt Roads Naval Base, PR (Naval Facilities Engineering Command, Atlantic Division, Norfolk, VA)

Description of need for this analysis. All DoD components have a requirement to respond to an oil spill under the Clean Water Act; the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); the Oil Pollution Act; the National Contingency Plan; other related Acts; and Navy regulations. At Roosevelt Roads Naval Base, NAVFAC must act both as the party responsible for the spill and as a Trustee for Federal lands under its management. The applicable legislation and regulations require NAVFAC to determine the extent of environmental damage from the spill and to carry out activities to correct the damage to natural resources that have occurred. NAVFAC is using a number of methods, including remote sensing, to identify the damaged areas and to plan and implement the restoration operation.

A large amount of fuel oil was spilled from storage tanks at the Roosevelt Roads Naval Base in Puerto Rico (Figure 41) into mangrove habitat fringing the adjacent harbor. The Navy responded quickly to the spill and contained the spill. However, the spilled fuel damaged a 40-acre area of mangroves and possibly other natural resources in the harbor vicinity before the spill was contained.



Figure 41. Roosevelt Roads is a Naval Facility on the eastern end of Puerto Rico near Ceiba.

General description of procedure. NAVFAC used high-resolution classified imagery to help determine the extent of the damaged mangrove and submerged benthic areas. Images from the national classified imaging systems was used for analysis in conjunction with other types of remote sensing imagery, with data from airborne and other commercial sensors, and with on-the-ground measurements and observations.

Imagery resources required. High-resolution classified images.

Results. Environmental personnel with appropriate security clearance used the classified imagery. They determined that the imagery was very useful for delineating and analyzing the mangrove area damaged by the oil spill.

Conclusion. Classified imagery is a very useful resource for helping to determine the extent of environmental damage from oil spilled into the environment.

Application Area: Extending Management and Climate Change Trend Analysis Baselines

Installation location used. Yuma Proving Ground, AZ

Description of need for this analysis. Aerial imagery has shown areas in and around the Yuma Proving Ground with small (about 3-meter diameter) barren areas or “white spots” as seen in aerial photographs. These white spots appear to be located within sagebrush communities. In this application, it is hypothesized that individual *artemisia* sp. plants have died leaving exposed areas that are highly reflective, thus giving rise to these white spots. In coordination with more recent imagery evaluations, the Corona imagery was evaluated as to its ability to document the presence of this spotting, establish a longer temporal baseline, and test this hypothesis.

General description of procedure. Two Corona images were rectified to a Landsat TM image; the Corona image was found to cut across the boundary of the military installation (Figure 42). Due to the absence of an intense road network, the drainage network, particularly the intersections, served as the location of GCPs. The resampling procedure applied to this data set was the Nearest Neighbor resampling method. A visual analysis of the two Corona images was conducted to locate the areas where spotting occurred and determine the cause of the spotting in this region. The portions of the Corona images that extended beyond the Landsat TM image were observed to have some spotting and therefore were included in this study. The Landsat TM image did not show any areas with spotting; however, some image process models were applied to provide correlation information about the areas with spotting.

Imagery resources required. Two December 1965 Corona images were used with an April 1994 Landsat TM image. These two Corona images were scanned from filmstrips and were chosen as the most suitable portions that fell within the study area. An image showing the approximate boundary of the Yuma facility and the approximate location of the study area was also made available. The boundary data were transformed from the initial format to an ArcInfo coverage using the import function in ERDAS Imagine version 8.4. This was followed by a visual comparison of the Corona and Landsat TM image.

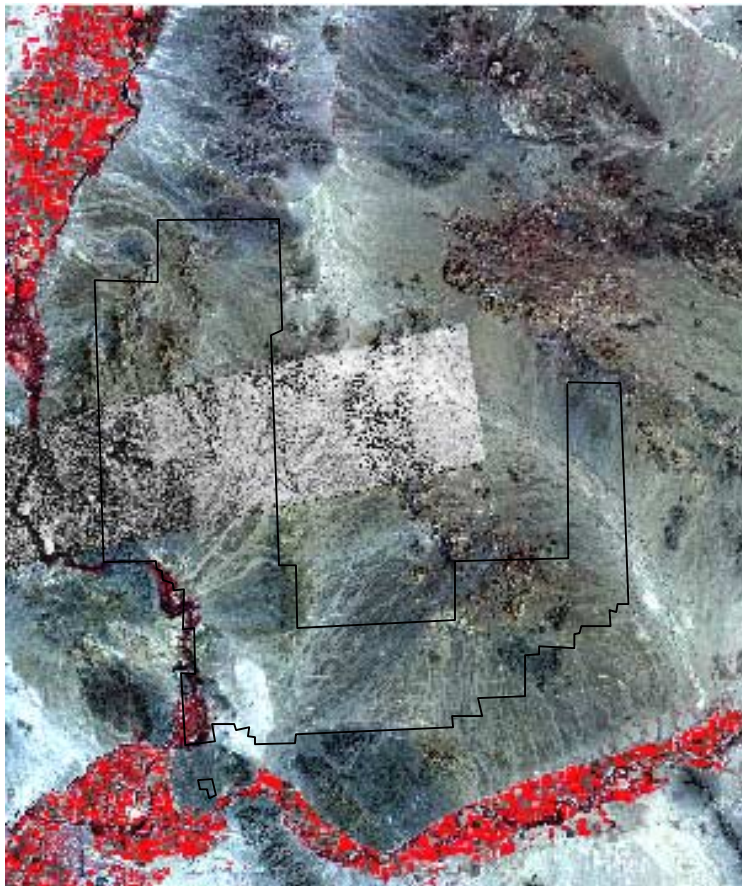


Figure 42. Corona image, Landsat TM image overlay, and boundary layer.

Specific procedure.

1. **Color Table Modification of Corona Image:** Both of the Corona color tables were modified to determine if the spotting could be clearly separated from the surrounding terrain. The rectified Corona images were converted from a continuous file to a thematic file using SUBSET. The colors within the color table of the thematic Corona files were changed and displayed on the Viewer.
2. **Visual Analysis of Corona Image:** A visual analysis was conducted to identify the location of the areas where spotting was present. The visual analysis used ERDAS Imagine version 8.4 software with the Viewer display set at standard deviation. Two areas of "spotting" were classified: significant/clear and faint (Figures 43 and 44).
3. **TM Processing:** Several models were applied to the Landsat TM imagery: principal component 2 analysis, vegetation index (band4 – band3), iron oxide (band3/band1), clay minerals (band5/band7), ferrous minerals (band5/band4), mineral composite (band5/band7, band5/band4, band3/band1), and hydrothermal composite (band5/band7, band3/band1, band4/band3).

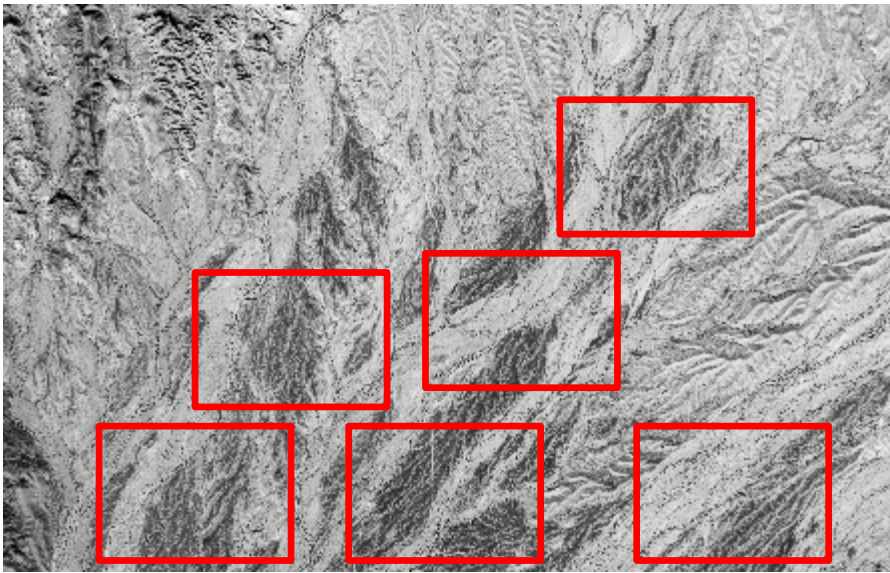


Figure 43. Areas of clear pattern of spots.

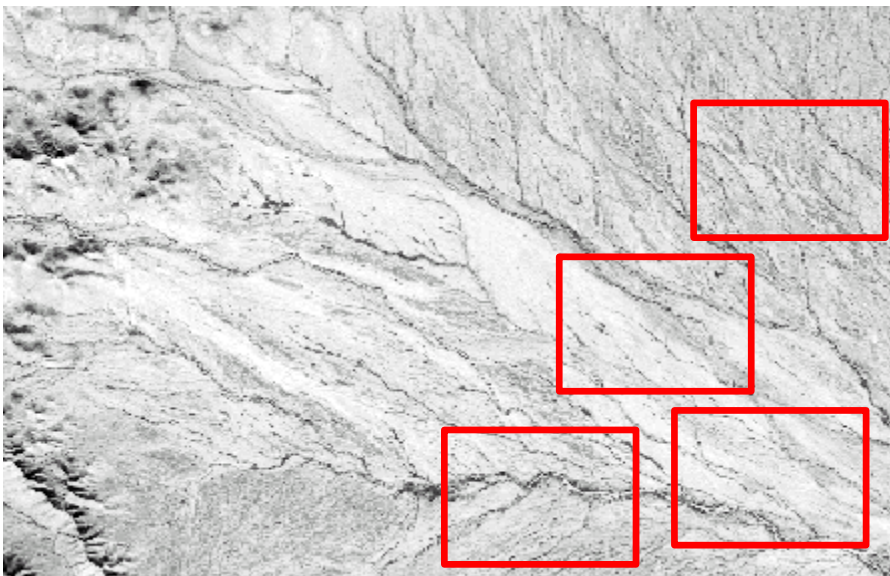


Figure 44. Areas of faint spots.

4. Preprocessing:

Scan Corona filmstrip film at 5000 dpi

Yum7a.img to yum7a_rtm.img

Note: Due to the lack of road networks, the only suitable option was the extensive stream network, which served as the best alternative to the location of GCP.

RMS: 852.20 for Corona transformation to UTM (DATUM/ZONE) based on TM

GCP: 43 for Corona transformation to UTM (DATUM/ZONE) based on TM

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: Overlap of areas

Scan Corona filmstrip film at 5000 dpi

Yum7b.img to yum7b_rtm.img

RMS: 1937.18 for Corona transformation to UTM (DATUM/ZONE) based on TM

GCP: 57 for Corona transformation to UTM (DATUM/ZONE) based on TM

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: Overlap of areas

Results.

1. **The Corona imagery:** The Corona imagery has provided evidence that the vegetation was the cause of the spotting.
 - The Corona imagery shows consistent spotting occurs only in areas of flat to nearly flat terrain (Figures 43 and 44). Spotting can be found in nonflat areas, but is likely due to other causes (see Film Anomalies page 81).
 - The spotting pattern is closely related to the river terrain (Figures 45 and 46).
 - A similar spotting pattern can be observed with live vegetation (Figure 47).

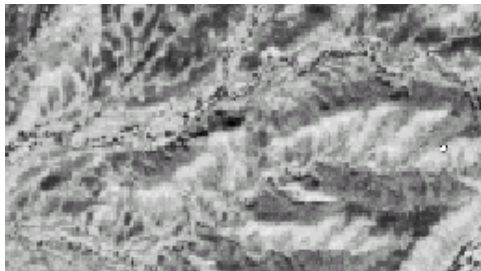


Figure 45. Examples of spot river patterns.

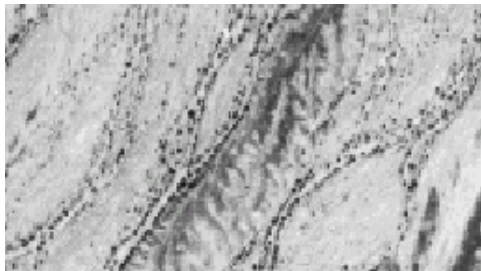
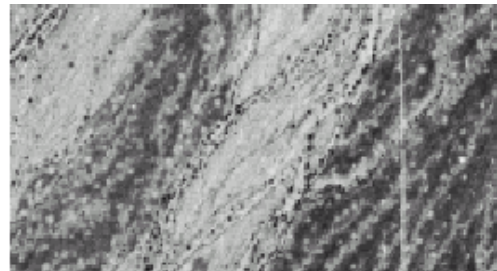
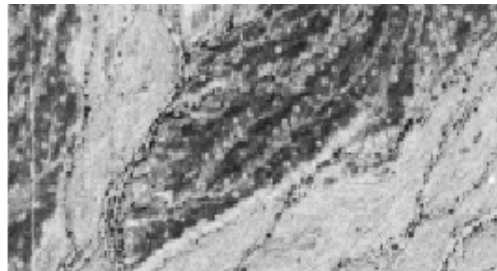


Figure 46. Examples of spot patterns.



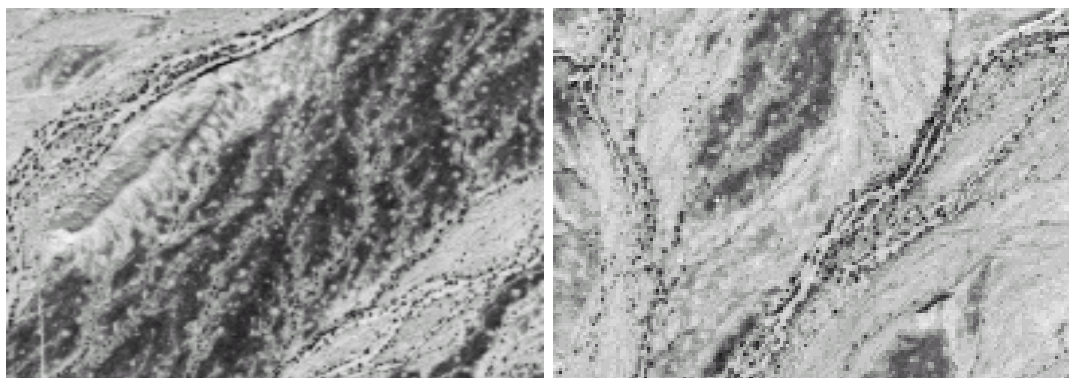


Figure 47. Spotting example (white spots) and vegetation example (black spots).

Figure 47 (left) shows an area of white spotting while Figure 47 (right) shows an area of vegetation spotting. Because these spotting patterns are extremely similar, closely related to the river terrain, and they are found in nearly flat terrain, it is likely that the live vegetation found in Figures 45, 46, and 47 are the cause of the spotting.

2. **TM Imagery:** The Landsat TM image did not show any spotting in areas that had spotting in the Corona images. This is most likely due to the pixel limitation (30 m) of the TM imagery that was too large to detect the areas of spotting. The Landsat TM can be used as an indicator to where areas of spotting are most likely to occur. Landsat TM shows (Figure 48) a visual correlation between lighter and darker areas where spotting occurs (Figure 48). The clay minerals example (Figure 49b) shows a correlation between areas of spotting (Figure 49a) and clay mineral deposits shown in dark. The hydrothermal composite example (Figure 49c) shows a correlation between areas of spotting and the hydrothermal return shown in dark green. The mineral composite example (Figure 49d) shows a correlation between areas of spotting and mineral deposits shown in bright green.

Due to the lack of vegetation, principal component and vegetation index analyses were not useful. The iron oxide and ferrous mineral models also were not useful.



Figure 48. Corona image (left) dark areas with spotting and Landsat TM (right, Bands 4,3,2).

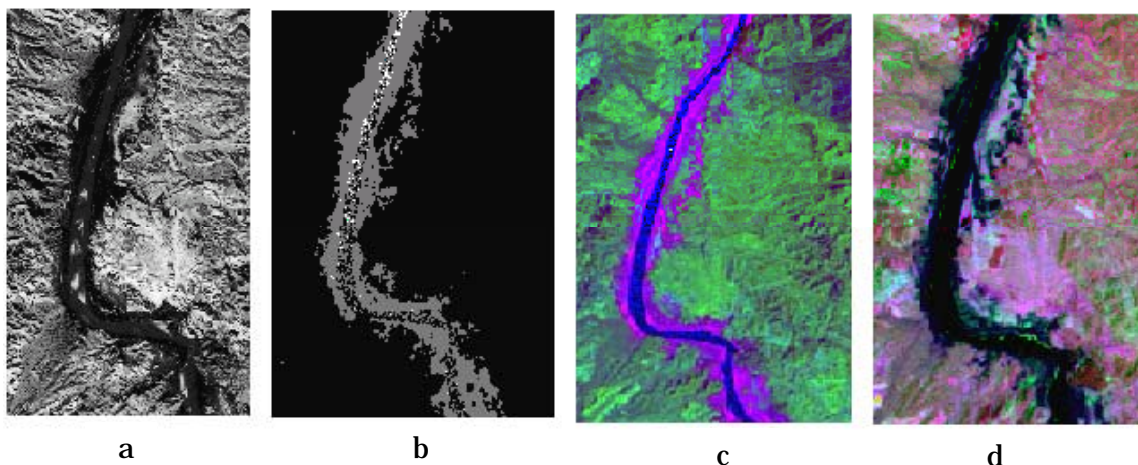


Figure 49. Correlation of spotting (a) and clay minerals (b), hydrothermal composite (c), and mineral composite (d).

3. **Color Table Modification:** The color table modification results were fair when only focusing on a small area (Figure 50). Though some separation could be determined, the overall quality and usefulness of recoding, or classification as a reliable source of locating spotting, is negligible. If the spectral return of the surrounding terrain changes, the spotting becomes too difficult to separate from the ambient surface character.
4. **Film Anomalies:** One important finding is the presence of anomalies throughout the Corona images that were clearly unrelated to the ground conditions of the Yuma area. These anomalies were very similar to the white spotting found in Yuma groundcover. The spectral similarity between anomalies and the spotting is high, with the anomalies tending to be brighter than the spots. The shape and size of the anomalies varied and could be used to identify them as anomalies and not spotting. Dust is the most likely cause of these anomalies. Figure 50 shows that the anomalies are found inside and outside the areas where imagery is recorded.
5. **Statistical Analysis of Spotting (Vegetation Pattern):** Within a region identified for detailed analysis, Sections A and B were defined (Figure 51). From each section, a set of samples for the white spots (for the purposes of this evaluation only, referred to as “poor vegetation”) was taken. Also, samples from each of the sections of dark spots (for the purposes of this evaluation only, referred to as “healthy vegetation”) were taken for comparison. The perimeter sizes of the “spots” are shown in Table 6.

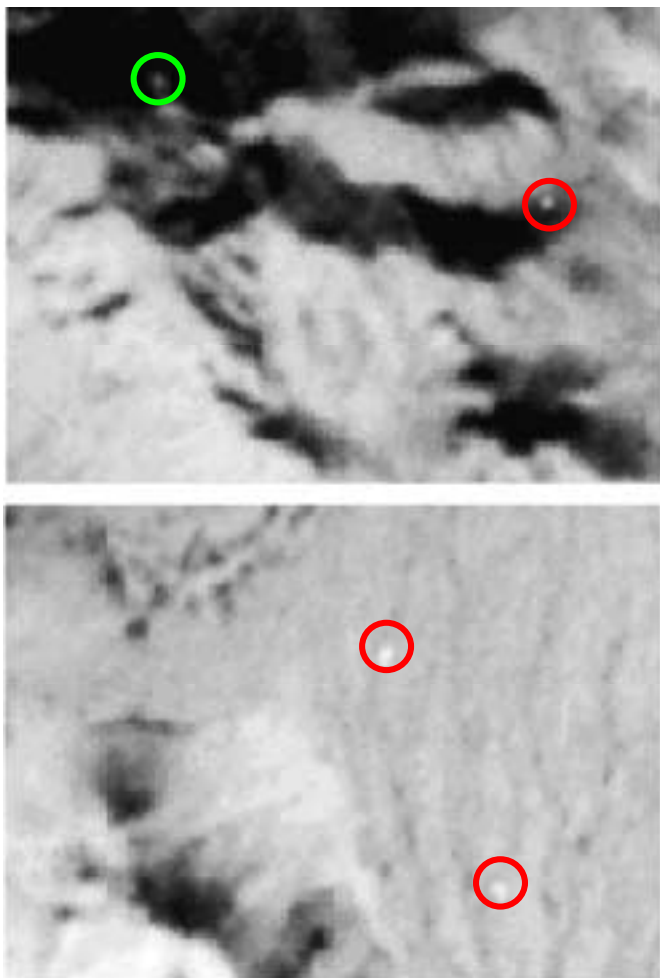


Figure 50. White dots caused by film (red inside recorded imagery, green outside recorded imagery).

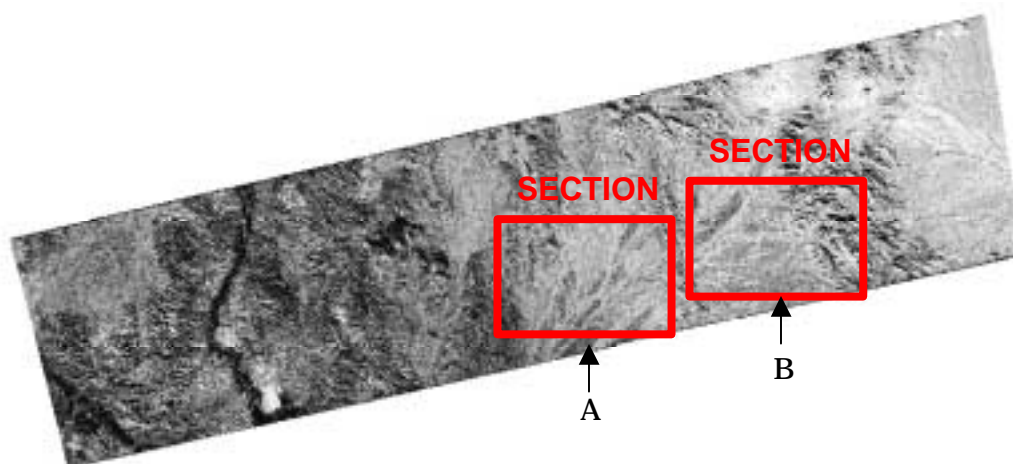


Figure 51. Locations of Sections A and B; areas from which samples were taken.

Table 6. Perimeter size data collected from Sections A and B.

Poor Vegetation				Healthy Vegetation			
Section A		Section B		Section A		Section B	
A		B		Healthy		V12	
Ellipse Perimeter (m)	Pixel Value	Ellipse Perimeter	Pixel Value	Ellipse Perimeter	Pixel Value	Ellipse Perimeter	Pixel Value
37.76	192	44.43	167	38.23	72	43.72	26
49.68	197	36.96	167	38.23	57	31.8	50
38.23	175	34.73	171	38.23	66	45.32	48
34.91	184	31.71	171	31.8	57	26.52	61
40.85	187	25.41	171	43.72	73	50.28	37
43.72	192	31.71	167	31.8	49	50.04	38
46.8	192	36.96	171	31.8	55	38.23	50
37.76	184	40.57	180	43.72	43	38.23	60
46.8	187	36.96	212	31.8	45	50.04	32
40.85	184	34.73	184	31.8	38	33.96	68
34.91	163	32.34	187	50.04	49	43.72	34
40.85	192	36.96	192	38.23	57	31.8	52
40.85	175	34.73	187	31.8	48	38.23	35
34.91	183	34.73	175	31.8	69	38.23	52
40.85	187	43.89	180	31.8	54	31.8	53
31.8	171	36.96	184	31.8	46	31.8	49
37.76	187	36.96	180	43.72	59	38.23	43
34.91	171	34.73	111	19.87	77	43.72	42
46.8	187	34.73	175	31.8	56	26.52	68
40.85	192	44.43	187	43.72	57	31.8	52
37.76	175	40.57	175	43.72	54	31.8	48
40.85	184	34.73	171	43.72	59	26.52	45
43.72	187	34.73	175	38.22	56	38.23	42
44.13	184	36.96	175	33.96	57	38.23	50
43.72	184	40.57	180	38.23	57	38.23	72

The data were divided into six classes: 20-25, 25-30, 30-35, 35-40, 40-45, and 45-50. Because some of these groups (classes) contain zeroes, a reclassification was necessary for the validity of the statistical procedure that was used. Thus, Table 7 shows the new classes. Comparisons of the vegetation in Sections A and B were conducted.

Table 7. Classified data.

	White Spots		Healthy Vegetation	
Perimeter Size* (m)	Section A	Section B	Section A	Section B
≤ 35	5	12	12	10
35 – 40	5	7	6	8
> 40	15	6	7	7
Means	40.48	36.48	36.54	37.48

* The smaller the mean perimeter, the healthier the vegetation.

1. Comparison of poor vegetation (white spots) in Sections A and B.

Null Hypothesis: Conditions of white spots (poor vegetation) do not change between Sections A and B.

A Chi-squared test was carried out to compare the poor vegetation in Sections A and B using the statistical package SPSS. The results are in Table 8 and Figure 52. A Chi-square of 7.073 corresponding to a low p-value of 0.029 indicates that the observed values and the expected values in the two sections are different. Hence, the null hypothesis is rejected. The data support the fact that some variations exist in the poor vegetation when you compare the two sections.

Table 8. Chi-squared test results comparing the vegetation health in Sections A and B.

Chi-Square	df	p-value	N
7.073	2	0.029	50

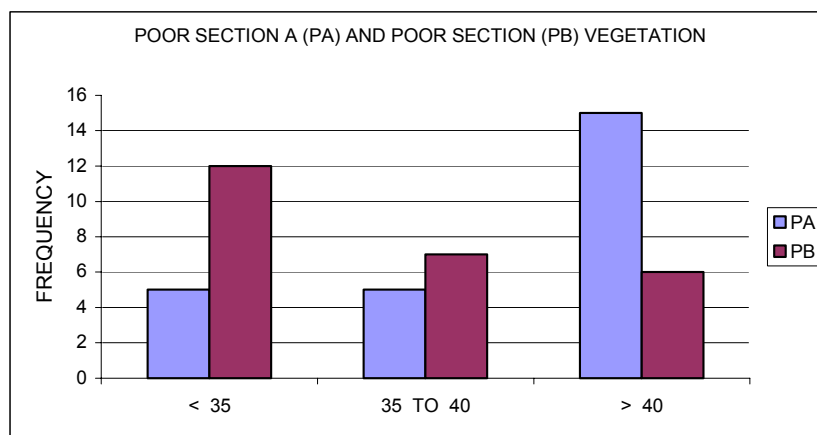


Figure 52. Plot comparing the vegetation health in Sections A and B.

2. Comparison of the poor and healthy vegetation in Section A.

Null Hypothesis: There is no difference between the poor and healthy vegetation in Section A.

A similar Chi-squared test was performed to compare the vegetation health on Section A. The result, contained in Table 9 and Figure 53, shows that the difference is barely significant at 95% (p-value = 0.053). Their difference would be declared as significant at, for example, any significance level ≥ 0.06 . At a significance level of 0.05, one cannot reject the null hypothesis and may conclude that in fact there is no difference between the poor and healthy areas.

Table 9. Chi-squared test results comparing vegetation health on Section A.

Chi-Square	df	p-value	N
5.882	2	0.053	50

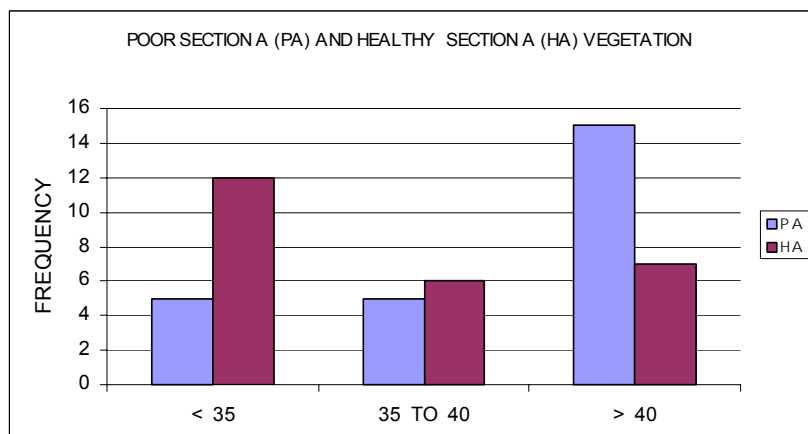


Figure 53. Plot comparing the poor and healthy vegetation in Section A.

3. Comparison of poor and healthy vegetation within Section B

Null Hypothesis: There is no difference between the poor and healthy vegetation in Section B.

The same Chi-squared test as in the above for Section A was performed in this case. Here the result is not significant at all ($p\text{-value} = 0.85$). The small Chi-square statistic (0.325) corresponding to a high $p\text{-value}$ suggests that there is no significant variation in vegetation health within Section B (Table 10 and Figure 54).

Table 10. Chi-squared test results comparing vegetation health on Section B.

Chi-Square	df	p-value	N
0.325	2	0.85	50

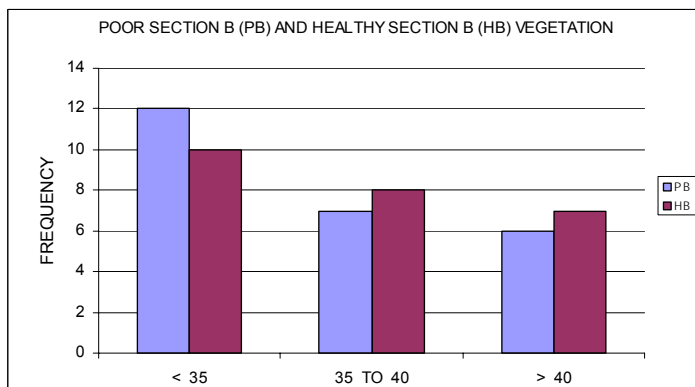


Figure 54. Plot comparing vegetation health on Section B.

Recommendation from statistical analysis. On the basis of this statistical analysis, the vegetation trend comparison efforts are more likely to be fruitful if concentrated in Section A.

Conclusions. The Corona imagery provides an outstanding and unique source for identifying areas of white spotting. It is superior to the Landsat TM image, which does not provide the resolution required to identify the location of these white spots. Landsat TM imagery, however, can provide information as to the conditions that contribute to the spotting.

It is extremely unlikely that the areas of spotting are caused by manmade activities. Based on the information provided from the Corona and TM imagery, it is most likely that the white spots are caused by natural events, such as vegetation disappearance. The imagery cannot determine what kind or type of vegetation is responsible for the spotting.

If the cause of the spotting is due to vegetation change, it is possible that this could be an indicator of climatic change for this region, most likely toward a drier climate. Obviously, more work is required to test this hypothesis.

The Corona images can be used to statistically identify areas that are likely the best locations for more detailed analyses.

Users should be aware that the Corona film contains anomalies, most likely caused by dust on the film when developed or scanned to digital format. In this application, the visual appearance of these anomalies was similar to the white spotting under investigation. However, statistical evaluation of the shape and size of the anomalies could be used to separate them from the spotting under investigation.

Application Area: Vegetation and Trend Analysis and Support for Regional Ecosystem Management

Installation location used. Fort Benning, GA

Description of need for this analysis. As a large and active Federal land holding, Fort Benning is liable to be blamed for changes in the region that are a result of cumulative changes in the way the land is owned and used, outside of its boundaries. In this application, we wish to identify how the ecosystem, as determined by land cover types, has changed since the early 1960s. The purpose is to define the extent of responsibility that Fort Benning has to contributing to change within the regional context. This could provide a basis in defining and limiting the government's legal and financial liability. Developing an objective historical baseline using archival imagery may help the government prevail in "nuisance" legal actions to which the Fort is occasionally subjected.

General description of procedure. There is a difference between land cover and land use in image processing. The results of this study require land use; while "classification" in image processing is best used to determine land cover. Due to this difference, confusion may result. This difference dictated the processes adopted for use in this study.

Two Corona images (1964) were compared to a SPOT (1990) and a Landsat TM (1992) image to determine land cover changes. To accomplish this, images were: (1) rectified and (2) clipped to comparable imagery boundaries, (3) clouds were removed, (4) an unsupervised classification was carried out followed by a (5) supervised classification; (6) certain classes of the supervised classification not of interest to the analysis were removed, (7) the remaining classes were recoded, and (8) the classified/recoded Corona images were mosaiced (put together).

Imagery resources required. The Landsat TM (May 1992), SPOT (September 1990), and Corona (October 1964) images. It was observed on arrival, that the Corona images used for this study showed bright lines across the images. These lines did not affect the results and the conclusions of this study. The Fort Benning boundary was used in the clipping process. It was used in comparing changes inside and outside the military installation.

Specific procedure.

1. **Preprocessing:** Scan Corona filmstrip film at 5000 dpi
RMS: 0.4 for Corona transformation to UTM (DATUM/ZONE) based on DRG
GCP: 10 for Corona transformation to UTM (DATUM/ZONE) based on DRG

North

RMS: 488.68 for Corona transformation to UTM (DATUM/ZONE) based on SPOT

GCP: 38 for Corona transformation to UTM (DATUM/ZONE) based on SPOT

RMS: 464.31 for Corona transformation to UTM (DATUM/ZONE) based on TM

GCP: 38 for Corona transformation to UTM (DATUM/ZONE) based on TM

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: Overlap of areas

Subsetting of TM and SPOT based on Corona Images

South

RMS: 374.97 for Corona transformation to UTM (DATUM/ZONE) based on SPOT

GCP: 32 for Corona transformation to UTM (DATUM/ZONE) based on SPOT

RMS: 387.31 for Corona transformation to UTM (DATUM/ZONE) based on TM

GCP: 38 for Corona transformation to UTM (DATUM/ZONE) based on TM

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: Overlap of areas

Subsetting of TM and SPOT based on Corona Images

2. **Clipping:** To compare change, all of the images were clipped (i.e., cut) based on the boundaries of the corresponding images. TM and SPOT images were clipped based on their boundaries. The two Corona images (roughly north and south of each other) were clipped based on the boundaries of the TM and the SPOT images. This process has three advantages: (1) smaller file sizes, (2) only the areas that can be compared are processed, and (3) decreases CPU time (see Figures 55 and 56.)

Due to differences in the appearance between the two images, the Corona images were classified separately before mosaicing occurred. The differences could be caused by one or a combination of processes: (1) atmospheric changes, (2) file processing, (3) file storage, (4) errors caused by generational processing, and/or (5) scanning differences.

3. **Unsupervised classification for TM, SPOT, and Corona images:** All images were classified based on an unsupervised classification method (ISODATA), provided by ERDAS Imagine 8.3. Unsupervised classification of 5, 10, and 20 classes were performed with 12 iterations and a .99 convergence threshold.

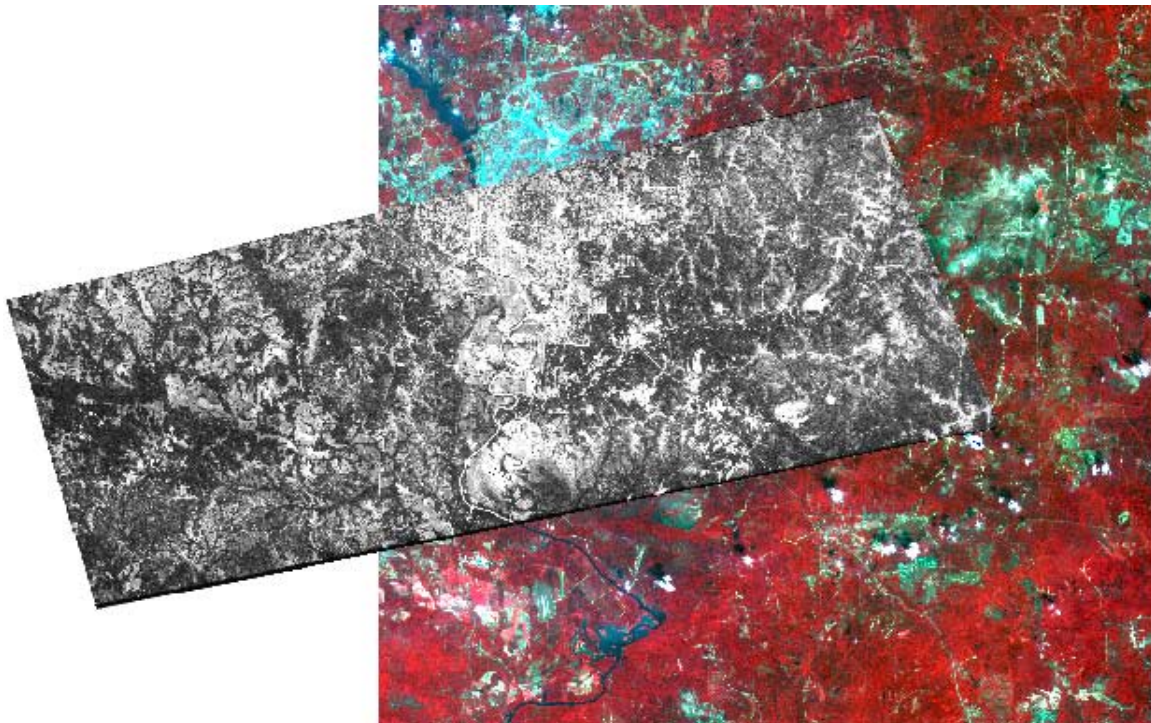


Figure 55. Before the clipping process, the Corona file size was 541 MB.

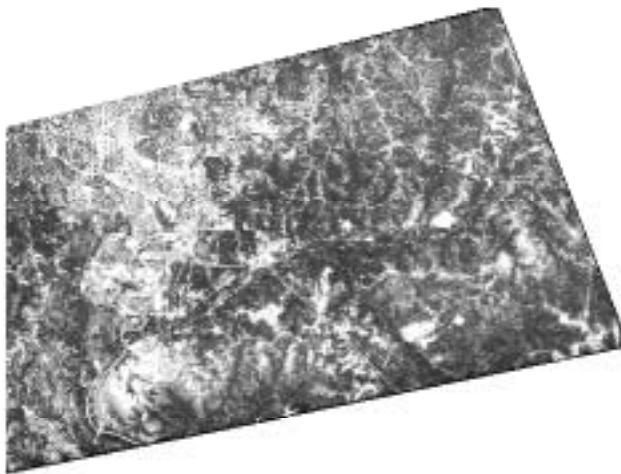


Figure 56. After clipping, the file size was 425 MB.

- **SPOT Image.** Due to the cloud cover in the SPOT image (Figure 57), unsupervised classification with 20 classes should be used only for quick reference; it was not used in this analysis. The separation between clouds and water bodies was good. Limited separation between water bodies and shadows occurred. Water bodies are not an important factor in the final analysis. This is an advantage because water and shadows were used together to mask features out of the image. There was poor separation between clouds, cleared

lands, and some other urban features. Swampy and agricultural areas cannot be clearly separated in the SPOT image. Since this study focused on the differences between developed and undeveloped areas and there is poor separation between swampy and agricultural areas, this input was not used.

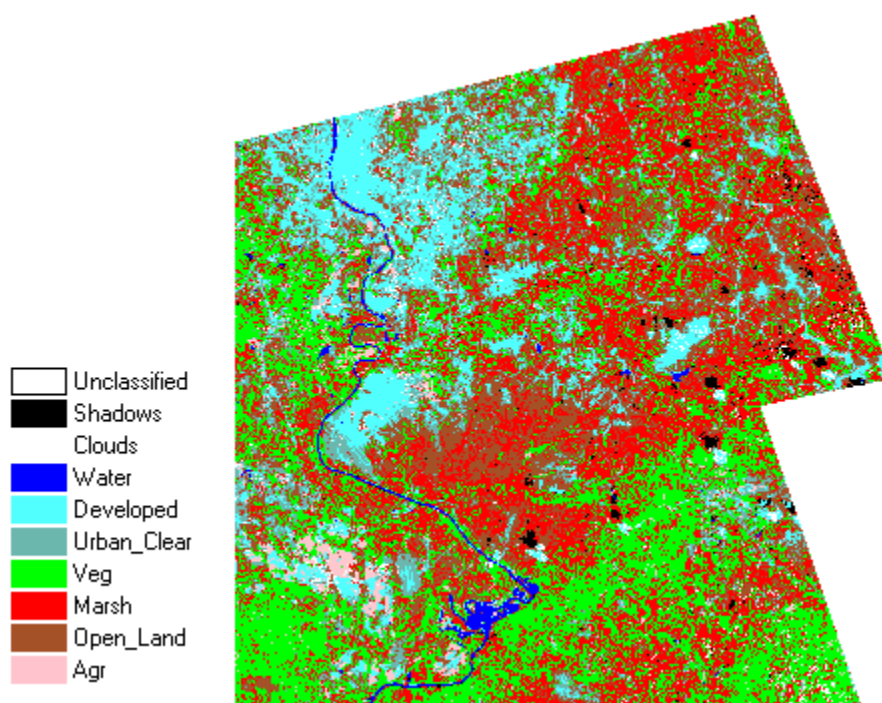


Figure 57. Supervised classification for SPOT image (10 classes).

For this SPOT image, unsupervised classification with 10 classes worked well for distinction of water, clouds, and shadow. The Imagine threshold routine, which determines the degree of reliability resulting from an image classification, did not result in a high confidence distinction between developed and undeveloped areas and therefore was not used.

- TM Image.** The Landsat TM image was completely cloud-free (Figure 58). After a good deal of experimentation, it was determined that an unsupervised classification with 20 classes can reliably distinguish between developed and undeveloped land cover areas (though there was some difficulty in separating cleared and developed areas). It was found that an unsupervised classification with 10 classes may produce unreliable results.

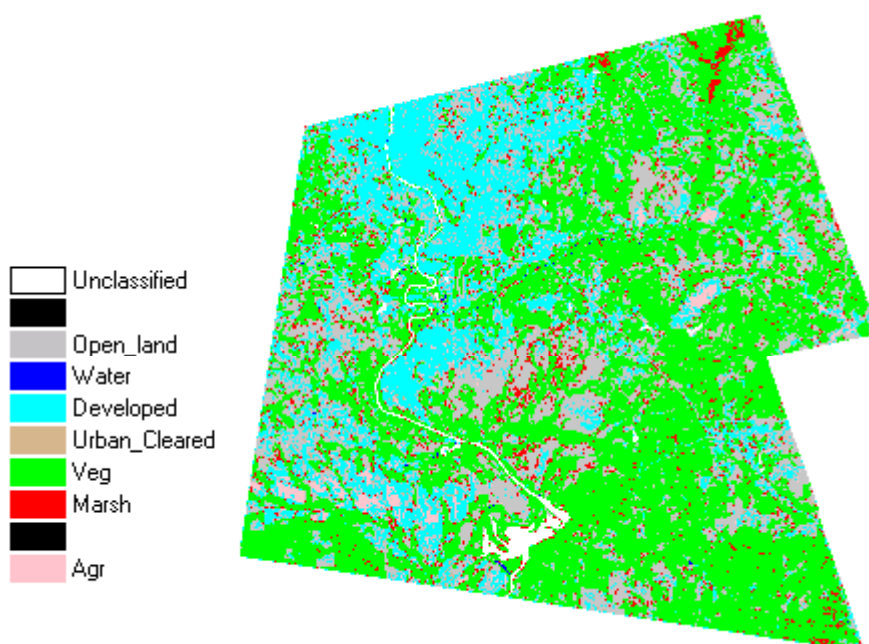


Figure 58. Supervised classification of Landsat TM image (10 classes).

- Corona Images.** In spite of the panchromatic character of the Corona images, it was found that applying an unsupervised classifier on the images resulted in an excellent and reliable means of determining the location of vegetation. The Corona images easily showed where and how much of the vegetation changed into built up areas. Despite the reliability and ease, there were two areas of confusion: (1) water, transportation systems, and developed areas were classified together and (2) marsh and wetland areas were classified together. Three unsupervised classifications were done with 5, 10, and 20 classes (Figure 59). A classification of just 5 classes resulted in a map that was too general and a classification of 20 classes became redundant. Because this study focused on the difference or change between developed and undeveloped areas, an unsupervised classification using 10 classes yielded the best results.
- Corona Reclassification.** The 10-class, unsupervised layers from Corona images were reclassified into two classes: undeveloped and developed. Categories 7 to 10 became undeveloped. They originally represented marshes, wetlands, and vegetative areas. Classes 1 to 6 were reclassified as developed. Classes 1 to 6 originally represented grasslands, open land, agriculture, water, urban, and open development.

To maintain consistency, both the northern and the southern images were reclassified with the same reclassification rules. It is worth noting that the northern and the southern images gave slightly different results for Classes 6 and 7 in the unsupervised classification. It is not understood why a different spectral re-

sponse exists since the images were taken on the same day only minutes apart. The difference might be due to a number of factors including the variations in the film, film processing, the scanning processing, or even variations in the atmosphere. Further investigation is warranted.

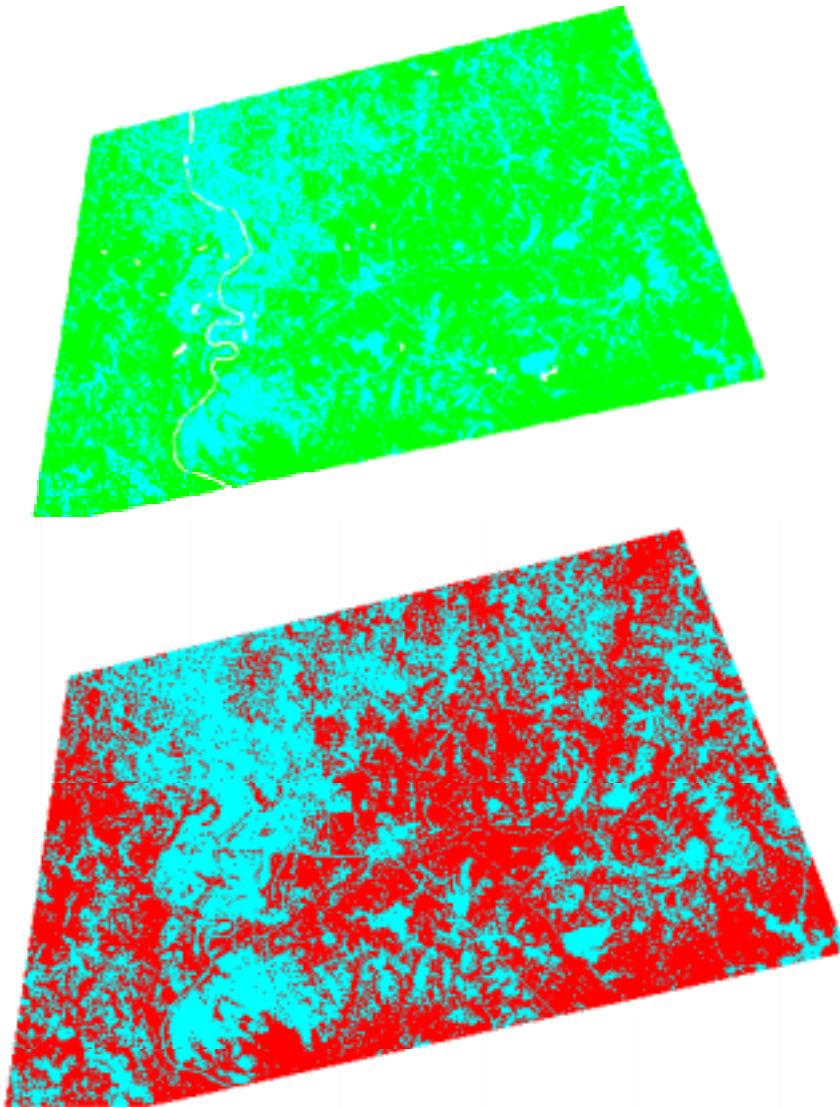


Figure 59. Unsupervised Corona classifications depicting 10 (top) and 20 (bottom) classes.

4. Supervised Classification for TM, SPOT, and Corona Images:

- **SPOT Image.** An initial process of cloud and shadow removal was carried out before the supervised classification (Figure 60). A supervised classification of the SPOT image was done using parallelepiped for the nonparametric rule, classify by order for the overlap rule (see Classification Order in the next paragraph), parametric rule for the unclassified rule, and maximum likelihood for the parametric rule.

Classification Order: Water (3), Developed (4), Vegetation (5), Marsh (6), Agriculture (7), Open_Land (8), and Urban_Cleared (9)

The classified images were simplified from 7 land cover classes to 2 land use classes: developed and undeveloped. Using a RECODE process, water, urban, agriculture, and cleared were classified as developed, while vegetation and marsh were classified as undeveloped.

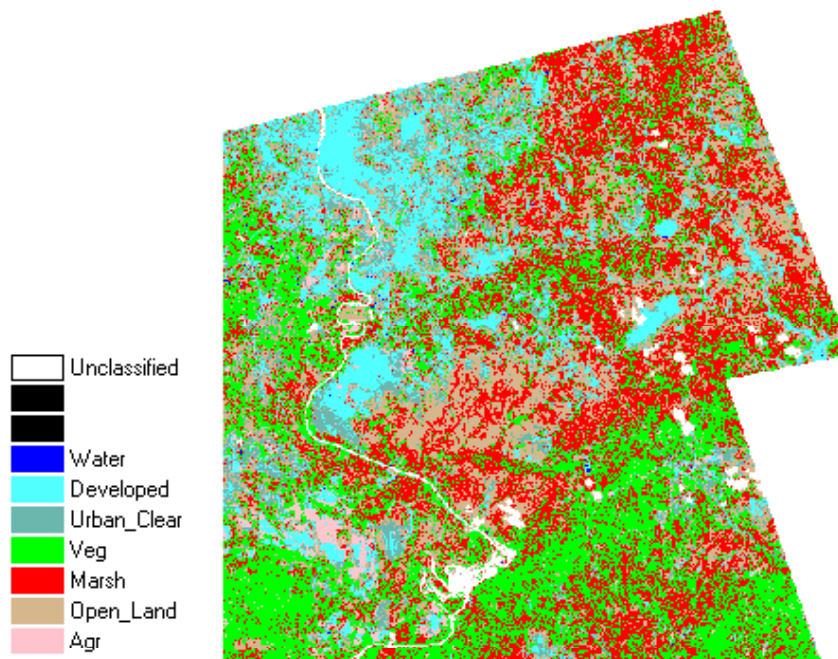


Figure 60. A supervised classification of the SPOT.

- **TM Image.** A supervised classification of the Landsat TM image (Figure 61) was done using parallelepiped for the nonparametric rule, classify by order for the overlap rule (see Classification Order in the next paragraph), parametric rule for the unclassified rule, and maximum likelihood for the parametric rule.

Classification Order: Water (3), Urban (4), Vegetation (5), Marsh/Wetland (6), Agriculture (7), Open_Land (8), and Cleared (9)

The classified images were simplified from 7 land cover classes into 2 land use classes: developed and undeveloped (Figure 62). Using a RECODE process, water, urban, agriculture, open land, and cleared were classified as developed, while vegetation, marsh/wetland were classified as undeveloped.

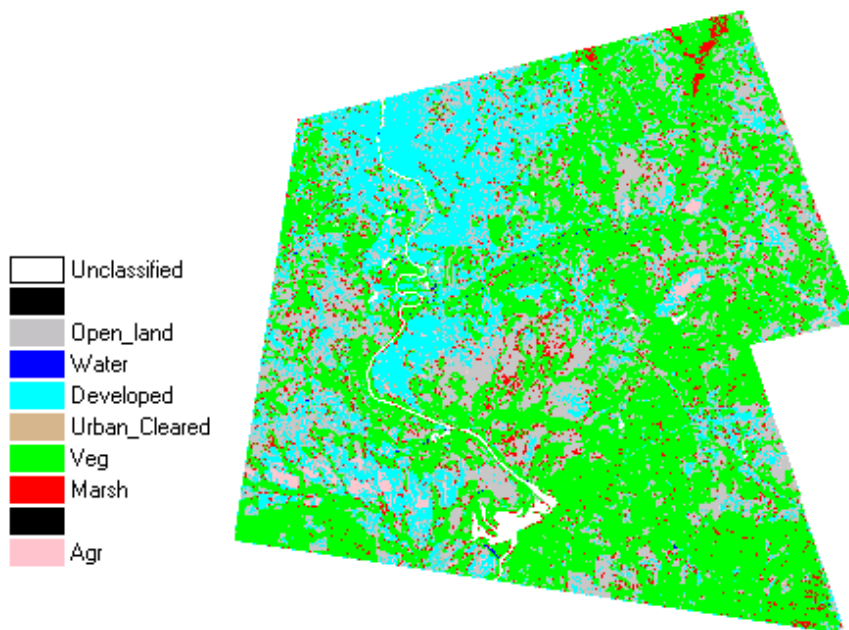


Figure 61. A supervised classification of the Landsat TM.

- **Corona Images.** Corona imagery is only panchromatic. Due to this spectral limitation, it made no sense to perform a supervised classification.
 - **Removal of Classes.** Due to the spectral confusion of clouds and water in the Corona images, the clouds and water bodies from all the images were removed. This process was performed with the seeding function in the AOI tool (Euclidean Distance 0.5) based on the classified images.
 - **Mosaic and Boundary Clipping.** Mosaicing was performed on the Corona image so that the statistical analysis would be easier. The four images were clipped into two files: areas inside and outside of the Fort Benning boundary (Figure 63).

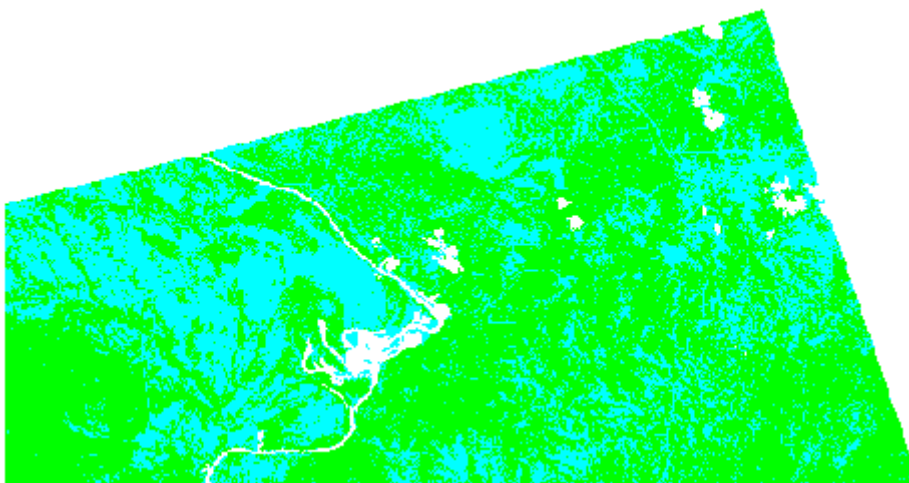


Figure 62. The simplification of 7 land cover classes to 2 land use classes.

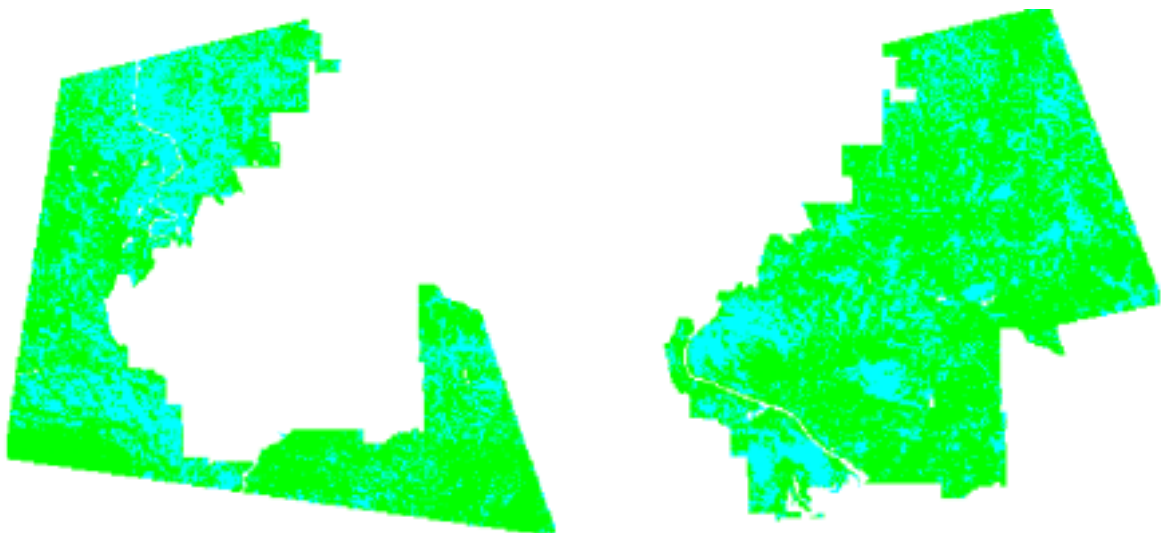


Figure 63. Outside (left) vs inside (right) the Fort Benning boundary based on the Landsat TM image and coordinated with the Corona image.

Conclusions. This example focused on identifying natural land cover change over the long term. Marsh/wetlands and water bodies could be easily identified using the Corona images. Corona images also provided an excellent and reliable resource for the identification of classes for TM and SPOT images. The Corona images are more valuable for identification of land classes than are the DRG files.

To compare Corona images to multispectral images (TM and SPOT), we simplified the classes of the multispectral satellite images to match those derived from the Corona image. The Corona images, like all panchromatic images are spectrally limited. Unsupervised classification for Corona is recommended over supervised. Unsupervised classification provides two important advantages:

1. The classes are created based on the ISODATA method, which is independent of user bias.
2. Unsupervised classification is quicker because samples do not need to be collected.

Recoding can be done in place of unsupervised classification; however, it should be done only with an analysis and some understanding of the study area and the data set. Recoding is quicker but is completely dependent on an analyst, which can introduce bias early in the processing.

Application Area: Extending Management and Climate Change Trend Analysis Baselines and BRAC Support

Installation location used. Pinon Canyon, CO, a subinstallation of Fort Carson

Description of need for this analysis. To establish a baseline before military acquisition (a Base Realignment and Closure, BRAC, issue). This helps to independently establish the characteristics of the land before it was acquired for military use.

General description of procedure. The initial process involved the geo-rectification to a reference SPOT image of one Corona image, portions of which fell within the boundary of the future Pinon Canyon Maneuver facility. With a relatively cloudy Corona image, it was still possible to collect an adequate number of GCPs. On identifying a prominent rail line and a variety of road intersections within the cloudless area, a sizeable number of GCPs were visible. The resampling procedure applied to this data set was the Nearest Neighbor resampling method. The boundary data vector coverage served as a guide to the location of the military site. The next phase involved clipping the overlapping boundaries and removing the clouds. This was followed by a visual inspection of the Corona and SPOT images.

Imagery resources required. The general image resources required were a Corona image dated June 1964 and a SPOT image dated June 1989. The coordinate system adopted for these images was the UTM, Clarke 1866 projection system.

Specific procedure.

1. **Preprocessing:** Scan Corona filmstrip film at 5000 dpi
Mosaicing scanned images
RMS: 652.14 for Corona transformation to UTM (DATUM/ZONE) based on SPOT
GCP: 48 for Corona transformation to UTM (DATUM/ZONE) based on SPOT
Geometric Correction Model: Polynomial Order: Second
Mosaicing Edge Matching Rule: none Subsetting of SPOT based on Corona Images
2. **Clipping Boundaries and Clouds:** The boundaries of both the SPOT and Corona images were used to acquire only the common areas shared between the two images. The removal of clouds from the Corona image was performed based on an observation analysis.
3. **Mask:** Using the results of the Corona image with the clouds removed, a mask was processed on the SPOT image, resulting in a SPOT image with the same ar-

areas removed that corresponded with the Corona image. Therefore, only the areas that were cloud-free in the Corona image were used in this analysis.

4. **Simple Spectral and Spatial Enhancements:** A number of simple spectral and spatial enhancements were executed to aid in the visual analysis.

One SPOT enhancement is calculating the vegetative index (Figure 64, right). This process enhances vegetation coverage in the original image (Figure 64, left). The vegetative index and the Corona images were recoded to add color and simplify the image.

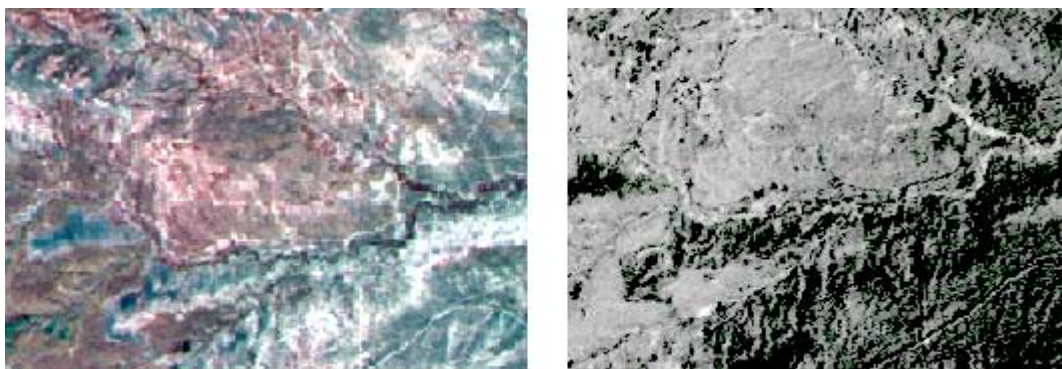


Figure 64. Simple spectral enhancements on SPOT image (left), vegetative index (right).

The Corona enhancements included an analysis called “texture.” A texture analysis is useful in detecting pixels that exhibit a large contrast with their immediate neighbors. Simply expressed, it enhances the edges of objects, structures, vegetation, and other targets as shown in Figure 65. The texture image in Figure 65 (right) shows the enhancement of the edges, here mostly of vegetation. Applying a slope extraction routine to the Corona image (as if the gray scale implied elevation) helps to define the extent of the plateau (Figure 66). This type of information can assist visual analysis.

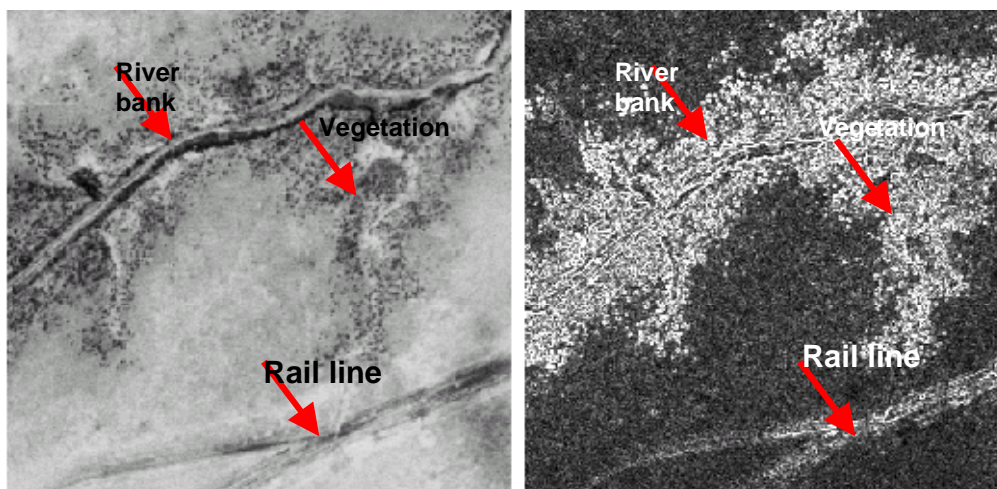


Figure 65. Corona (left) and texture (right) images.

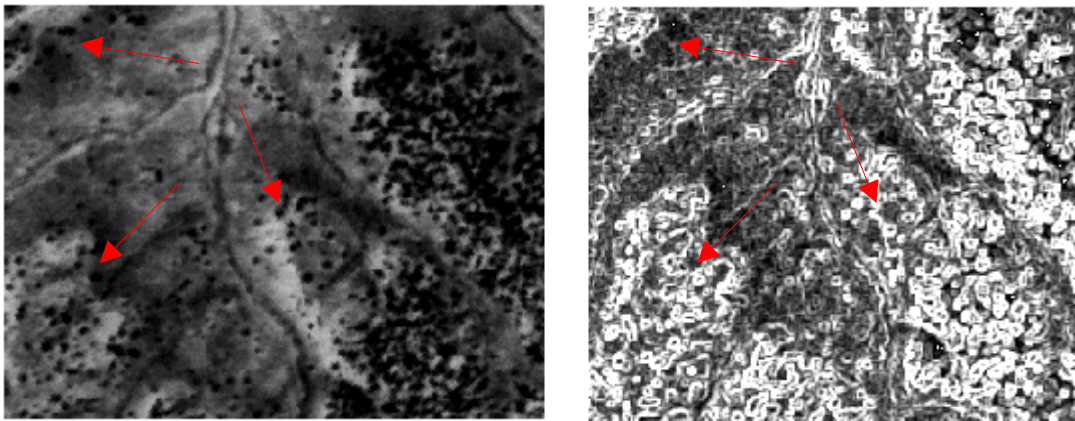


Figure 66. Plateau and slope identification.

Results. Visual inspection clearly indicates a difference between the amount of vegetation inside the Pinon Canyon area and outside its boundary. The SPOT data shows the vegetation within the Pinon Canyon boundary has increased when compared to the area outside (Figure 67).

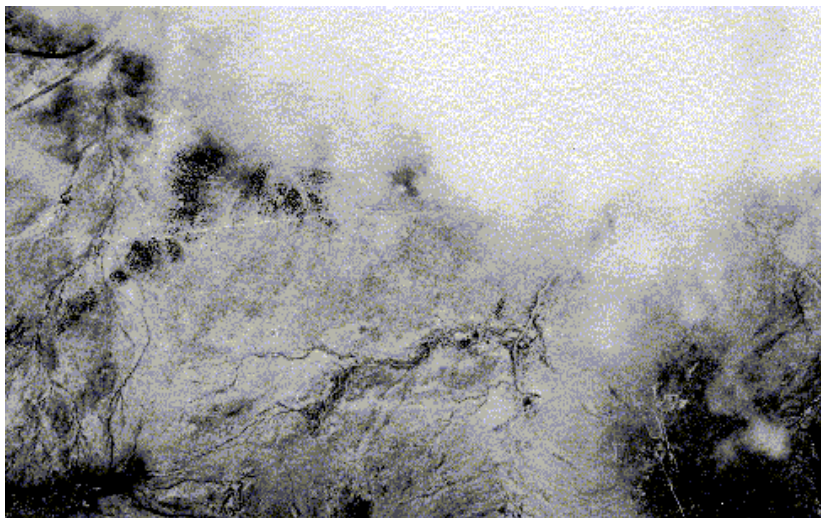


Figure 67. Manmade boundaries: 1964 Corona (top) image and 1989 SPOT (bottom) image.

The Corona image is useful for baseline land cover change analysis. A visual analysis shows that in 1964 there was limited difference between the vegetation inside the Pinon Canyon area and outside the boundary, both spectrally and spatially. The Corona image did show manmade boundaries inside what is now the Pinon Canyon area (Figure 67) so the Corona image had the resolution to show a change if it existed. Since very little area outside the boundary was cloud free, it would be more useful to have a cloud-free Corona image. Unfortunately, this is one of the shortcomings of using archival films; cloud-free coverage is not always available for a particular location.

The Corona image provided useful information on the location of structures and road networks that were present in 1964 and still remain. It is an excellent tool for locating unique structures (Figure 68). It was also useful in determining where new structures and road networks developed between 1964 and 1989.

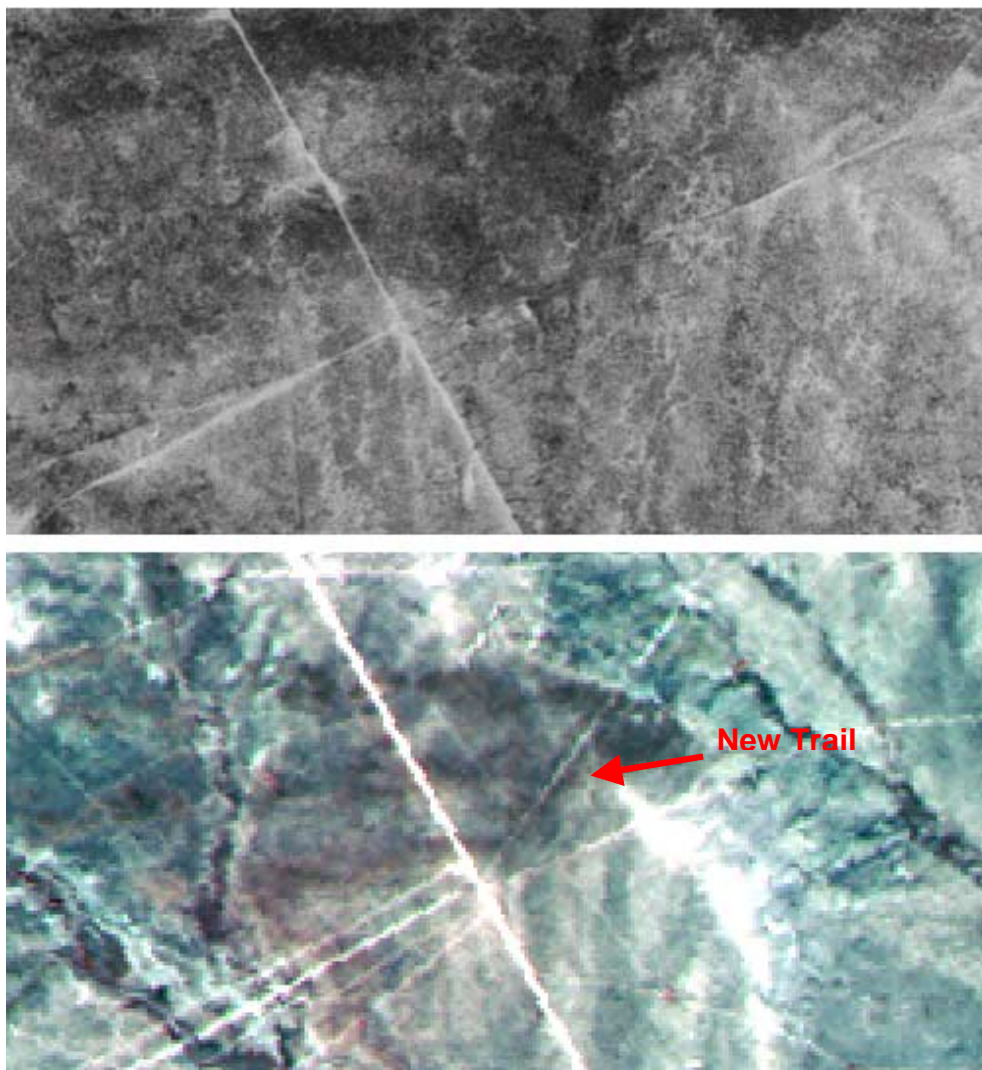


Figure 68. Recent developments/structures (1964 Corona above, 1989 SPOT below).

Based on visual analysis changes in vegetation on a regional scale are limited. Areas of change can be located (Figure 69); however, a regional analysis requires a more cloud-free image to provide reliable and unbiased evidence for climatic change.

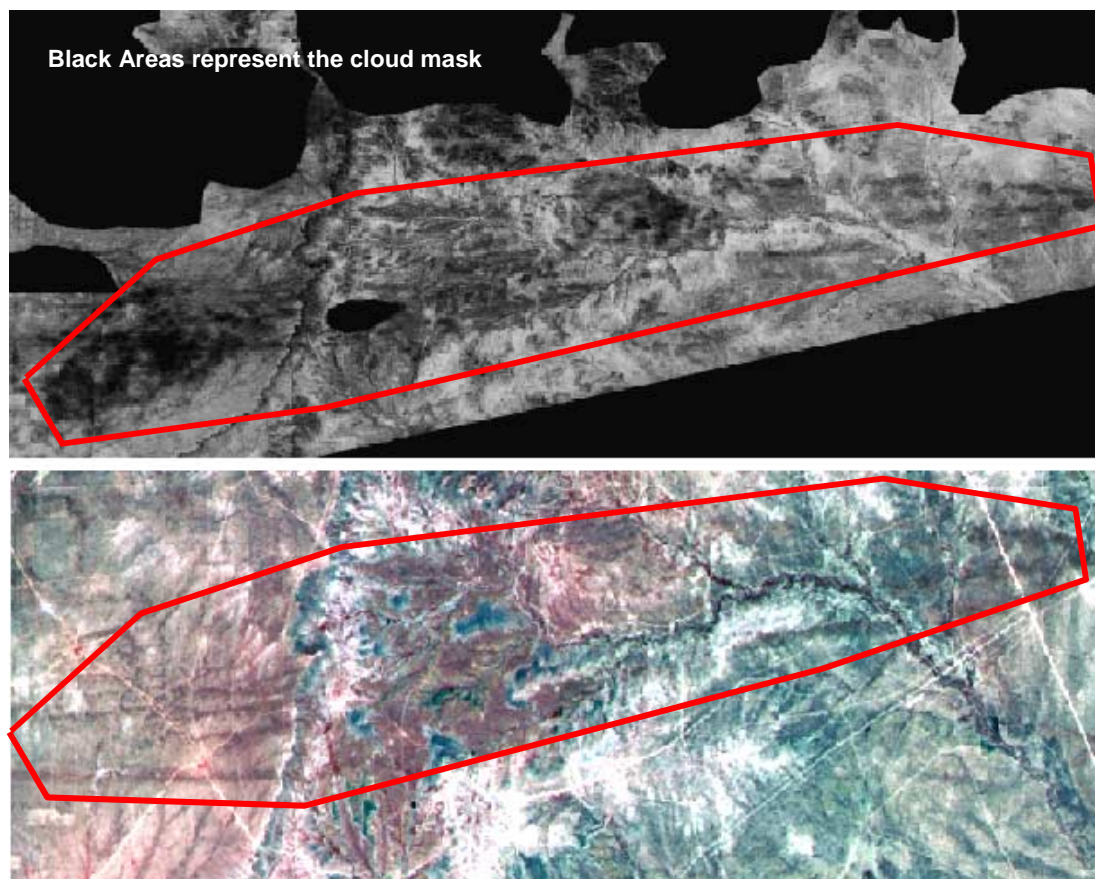


Figure 69. Unique structures and manmade features (the dark linear and semi-linear patterns that begin in the east, then spread out to the west).

Conclusion. Based on the visual results of the data used in this analysis, Corona data provides a creditable and reliable base for determining use change. Since much of the image near Pinon Canyon is cloudy, it would be nice to perform the analysis again with a cloudless Corona image. In spite of this and the panchromatic limitations of the original films, Corona images can be used as a completely reliable method to identify or establish a land cover character baseline, which can be used to compare a current situation with intense training to a situation before military acquisition.

Application Area: Arid Regional Ecosystem Management

Installation location used. Fort Huachuca, AZ

Description of need for this analysis. This task involved determining the capabilities of Corona imagery in assessing regional ecosystem change in a high desert environment. Ecosystems do not respect military boundaries, so the desire is to use a data source (Corona imagery) to extend historical trend baseline development. This is a current issue at Fort Huachuca as there is an Alternative Futures* study being carried on that uses 30 years of imagery data. At the same time, researchers wanted to focus in on a single cover type to support forestry management since Fort Huachuca forests share a high elevation boundary with the lands of Coronado National Forest.

General description of procedure. Although the qualitative analysis of data by the human eye may yield useful information, it is limited by the amount of data that can be analyzed.

1. An independently derived land cover classification was acquired to test the potential of Corona imagery to support a regional analysis. The Corona image was processed with an unsupervised classification into a small number of classes. The purpose was to determine how well the resource would support a generalized analysis.
2. In addition, to focus on one vegetative type, a comparison of TM and Corona images based on unsupervised and supervised classification was conducted. Four Corona images were rectified to a Landsat TM image, the Corona images formed a series of tiles when overlaid on the Landsat TM image. These images spanned the entire military installation. Due to the presence of an intense road network, particularly road intersections, it was possible to acquire a sizeable number of GCPs. The resampling procedure applied to this data set was the Nearest Neighbor resampling method.

Imagery resources required. Four Corona images dated March 1965 were used in conjunction with a Landsat TM image dated 8 June 1997. The four Corona images were scanned from filmstrips. For the regional analysis, the 1965, path 15 image was used. A land cover classification by EPA National Exposure Research Laboratory (NERL) derived from a 1997 TM image was used for comparison to the classified Corona image. For the forestry focus analysis, a section of the im-

* See <http://www.gsd.harvard.edu/faculty/steinitz/sanpedroriver.html>

age was clipped (covering roughly Garden Canyon) to depict only the southwestern area of Fort Huachuca. The installation boundary was used for reference.

Specific procedure.

1. **Preprocessing:** Scan Corona filmstrip film at 5000 dpi
 hua_15.img to hua_15_rtm.img
 RMS: 711.19 for Corona transformation to UTM (DATUM/ZONE) based on TM
 GCP: 52 for Corona transformation to UTM (DATUM/ZONE) based on TM
 Geometric Correction Model: Polynomial Order: Second
 Mosaicing Edge Matching Rule: none

 hua_16.img to hua_16_reg.img
 RMS: 867.52 for Corona transformation to UTM (DATUM/ZONE) based on TM
 GCP: 50 for Corona transformation to UTM (DATUM/ZONE) based on TM
 Geometric Correction Model: Polynomial Order: Second
 Mosaicing Edge Matching Rule: none

 Hua65_15_r_v3_gardencany.img to garden_cany_rtm.img
 RMS: 355.05 for Corona transformation to UTM (DATUM/ZONE) based on TM
 GCP: 24 for Corona transformation to UTM (DATUM/ZONE) based on TM
 Geometric Correction Model: Polynomial Order: Second
 Mosaicing Edge Matching Rule: none Nearest Neighbor resampling Method
2. **Clipping:** For the regional analysis, a section from the Upper San Pedro Study Area land cover, derived from 30-m classified 1997 TM image by EPA NERL, Las Vegas, was clipped to match the full extent of the hua_15.img file (Figure 70).

 For the forestry work, the Corona and TM images were clipped to include land areas that were high in elevation. The boundary of the area was selected using an AOI.
3. **Spectral enhancements:** For the forestry work, the Landsat TM image was spectrally processed, by applying a Principal Component Analysis (PCA). The spectral enhancement was applied in order to extract useful information contained within the multiband scene. The spectral enhancement process applied in this study was the Principal Component 2 (PC2 is used for Vegetation Analysis) and a Vegetation Index (Band 4 – Band 3).
4. **Stacking:** The TM layers were then merged with the original Landsat TM image using the “Stacking” function in ERDAS Imagine 8.4.

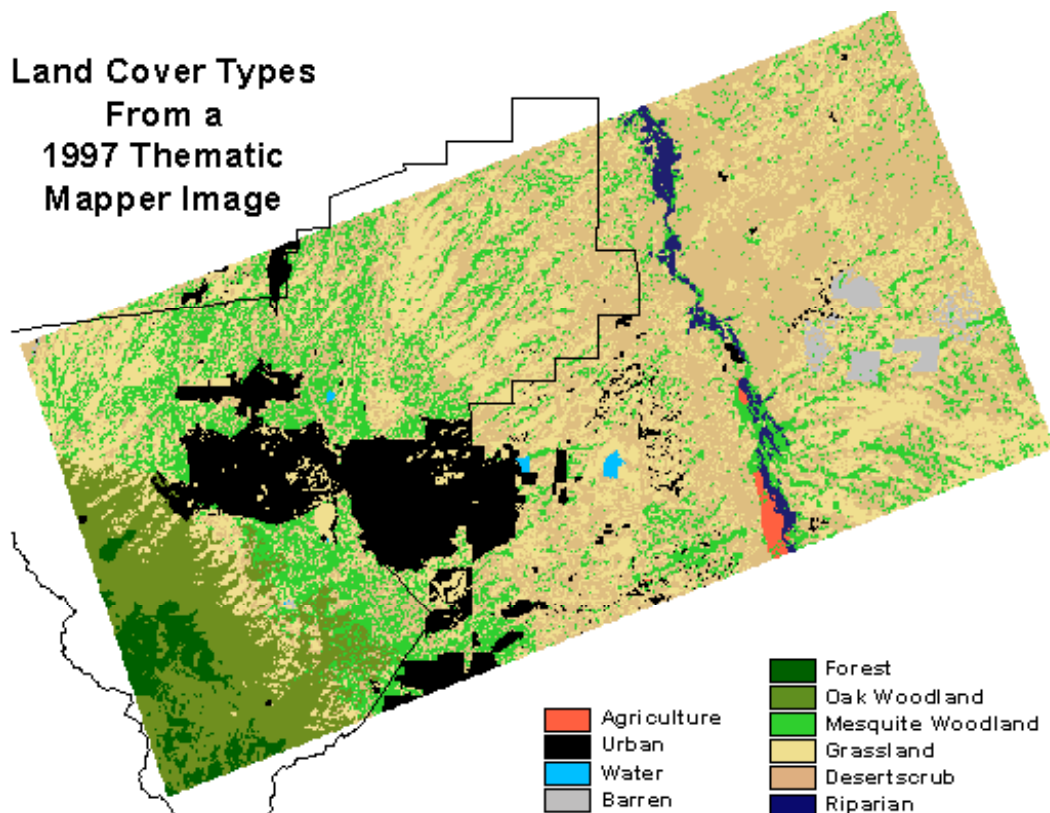


Figure 70. Clipped Upper San Pedro Study Area 1997 land cover from TM classification by EPA NERL.

5. **Unsupervised classification:** For the regional analysis, two unsupervised ISODATA clustering classifications of the Corona image were carried out requesting the final files have 6 and 10 categories.

For the forestry work, an unsupervised classification of the cloud-free Landsat TM was conducted using 20 classes. The classification grouped spectrally similar pixels together. The unsupervised classification was performed to provide a general picture of the forested areas.

An unsupervised classification of the Corona image was carried out in two ways.

- For the regional analysis, a generalization over a region that included the San Pedro River through the town of Sierra Vista and Fort Huachuca up to the ridge of the Huachuca Mountains.
 - A more specific unsupervised classification aimed toward use in identifying forested areas.
6. **Supervised classification:** A forest supervised classification was performed on the Landsat TM image. Pixels belonging to a specific surface type were used to generate a “type” (or training) set. Using a training set, it was possible to distinguish five main classes: roads, shadow, shrubs, and two types of forest.

7. **Subsetting:** A subset of the Corona image was created, converting it from a continuous format to a thematic format. This method was carried out using the subset function in ERDAS Imagine 8.4.
8. **Recoding:** The thematic Corona images color table (ranging from 0 to 255) was coordinated with the five classes in the Landsat TM image.

Result.

1. **Regional Ecosystem Management:** A coincidence matrix was run of the land cover types against the unsupervised, 6-category classification of the Corona image (Table 11).

Table 11. Known land cover types vs unsupervised Corona classification.

#	Land Use/Land Classification Type	Corona Classed VALUE_0	Corona Classed VALUE_1	Corona Classed VALUE_2	Corona Classed VALUE_3	Corona Classed VALUE_4	Corona Classed VALUE_5	Corona Classed VALUE_6
1	Forest	57600	12895200	165600	18000	3600	3600	7200
2	Oak Woodland	396000	41540400	9144000	1605600	266400	28800	25200
3	Mesquite Woodland	50400	13222800	37584000	22197600	13442400	11880000	1501200
4	Grassland	86400	13496400	45162000	37908000	27666000	30693600	4406400
5	Desert Scrub	68400	25668000	77317200	50108400	32508000	31647600	4413600
6	Riparian	3600	3297600	2390400	795600	428400	50400	39600
7	Agriculture	3600	277200	543600	622800	352800	126000	14400
8	Urban	25200	2620800	14004000	14252400	12978000	19411200	1969200
9	Water	0	32400	259200	255600	154800	118800	21600
10	Barren	0	446400	2098800	1562400	1360800	1476000	126000
	Total Count							629305200

Table 11 shows how the nearly 630 million pixels were distributed and Table 12 presents the percentage of distribution. The Corona Value Class was assigned to the Land Use category with the highest distribution (third from last column Table 12).

Table 12. Percentage relationship for land use vs Corona classification.

Corona Classed into 6 Categories: Percentage								Classified on Majority	# Incorrect Pixels	% in Cat. Incorrect Classed
	Corona Classed	Corona Classed	Corona Classed	Corona Classed	Corona Classed	Corona Classed	Corona Classed			
	Darkest		Gray				Lightest			
Land Use Type	VALUE_0	VALUE_1	VALUE_2	VALUE_3	VALUE_4	VALUE_5	VALUE_6			
Forest	0.01	2.05	0.03	0.00	0.00	0.00	0.00	Value_1	255,600	0.04
Oak Woodland	0.06	6.60	1.45	0.26	0.04	0.00	0.00	Value_1	11,466,000	1.82
Mesquite Woodland	0.01	2.10	5.97	3.53	2.14	1.89	0.24	Value_2	62,294,400	9.90
Grassland	0.01	2.14	7.18	6.02	4.40	4.88	0.70	Value_2	114,256,800	18.16
Desert Scrub	0.01	4.08	12.29	7.96	5.17	5.03	0.70	Value_2	144,414,000	22.95
Riparian	0.00	0.52	0.38	0.13	0.07	0.01	0.01	Value_1	3,708,000	0.59
Agriculture	0.00	0.04	0.09	0.10	0.06	0.02	0.00	Value_3	1,317,600	0.21
Urban	0.00	0.42	2.23	2.26	2.06	3.08	0.31	Value_5	45,849,600	7.29
Water	0.00	0.01	0.04	0.04	0.02	0.02	0.00	Value_2	583,200	0.09
Barren	0.00	0.07	0.33	0.25	0.22	0.23	0.02	Value_2	4,971,600	0.79
Column Total	0.11	18.04	29.98	20.55	14.17	15.17	1.99			
Total Percent							100		389,116,800	62%

From this assignment, the resulting Corona image classification would occur as in Table 13.

Table 13. Categorization of Corona unsupervised classification.

Land Use Type Category	Corona Category	% of Land Use Type in this Corona Category
Oak Woodland	Value_1	95.40%
Riparian	Value_1	4.08%
Forest	Value_1	0.53%
Desert Scrub	Value_2	56.68%
Grassland	Value_2	32.24%
Mesquite Woodland	Value_2	11.01%
Barren	Value_2	0.06%
Water	Value_2	0.00%
Agriculture	Value_3	100.00%
Urban	Value_5	100.00%

Figure 71 compares the Land Use Map for the classes of Oak Woodland, Riparian, and Forest with the classification of the Corona image of the same categories. In this illustration, the distributions look similar, particularly for the riparian areas along the San Pedro River. Table 5 suggests that only 2.45 percent of these categories are incorrectly distributed. However, this really means that of the three categories, only 2.45 percent of the Land Use cells were outside of these

locations on the Corona classification. Looking closer at some of the other categories, a much poorer match occurs. Though 100 percent of the Land Use Urban category fell within the resultant Corona Urban class, this class also included a huge amount of barren desert surface (Figure 72). That is, the result was inclusive but not adequately exclusive. In fact, for every correctly classified Urban cell, there existed four others that were not (Table 12, column "Value_5" where $15.17 - 3.08/3.08 \sim 4$). This example is more characteristic of the analysis. In fact, as Table 12 shows, 62 percent of the pixels were incorrectly associated by this technique. Though a good deal of urbanization has occurred in the intervening years between 1965 and 1997, it is clear from Figure 72 that the Corona Urban distribution for 1965 is not reasonable and cannot be explained by changed development patterns.

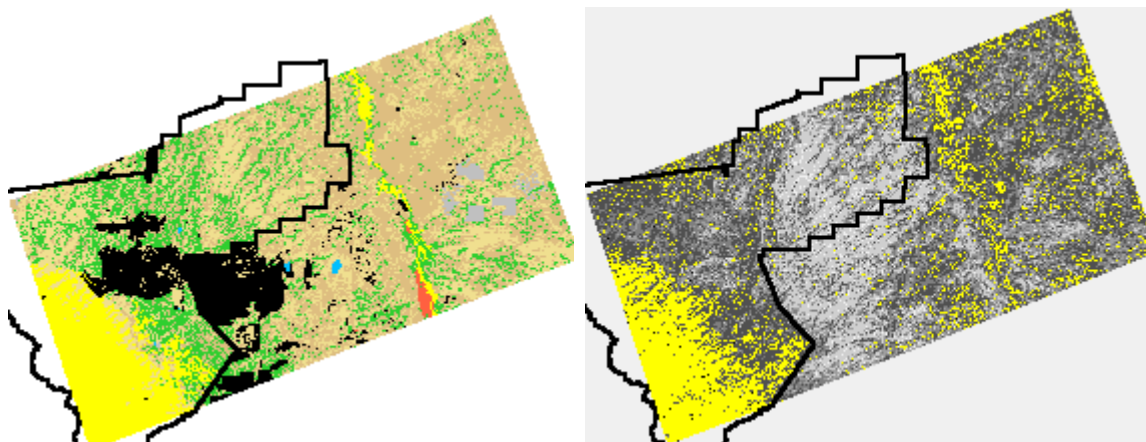


Figure 71. Land Use Map (left) with yellow indicating areas classed as Oak Woodland, Riparian, and Forest. Six category unsupervised classification of the Corona image (right) with the same categories highlighted in yellow.

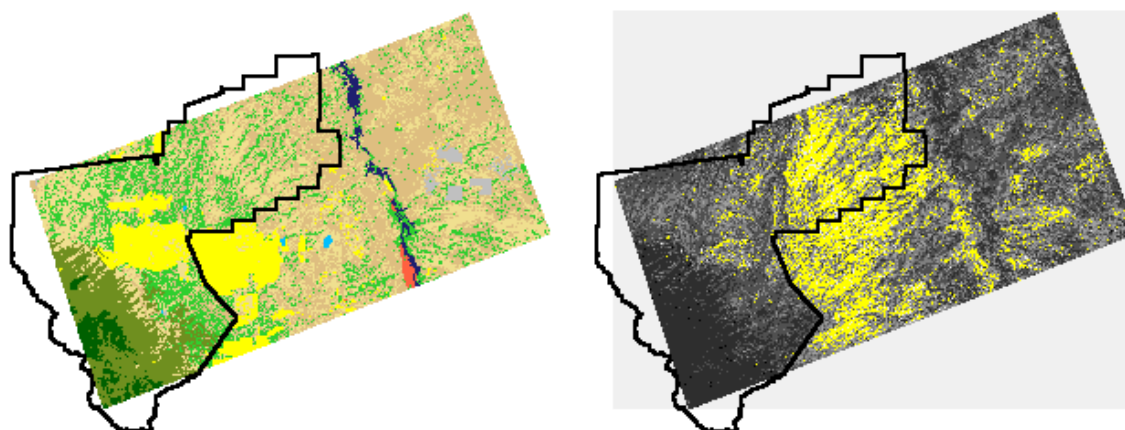


Figure 72. Areas defined as Urban from the Land Use file (left) and Corona classification (right).

A similar analysis was carried out in which the two most common categories (Grassland and Desert Scrub) were put into a single final class. Though the percentage incorrectly identified decreased to roughly 40 percent (Table 12, last column), this is still not very reliable. Also, increasing the number of types belonging to a category only serves to make that category too general to be useful. In summary, an unsupervised classification of the Corona image will not result in a useful land cover identification in a dry environment.

2. **Forestry ecosystem management:** Figure 73 shows the location of the forested areas on the classified Landsat TM image. Clear forested patterns can be observed on the higher elevations of the mountains as one might expect. The total forested area is 1,252 hectares. Figure 74 shows a classified Corona image. The Corona image does not exhibit the spatial pattern for the forest as in Figure 73. Since the forest areas were determined using a supervised classification, it is clear that more effort will not yield a better result. The classification of the Corona image is based on darkest areas, a limitation of the panchromatic nature of the Corona film. Unfortunately, dark areas can also be shadow areas, which occur commonly in mountainous regions.

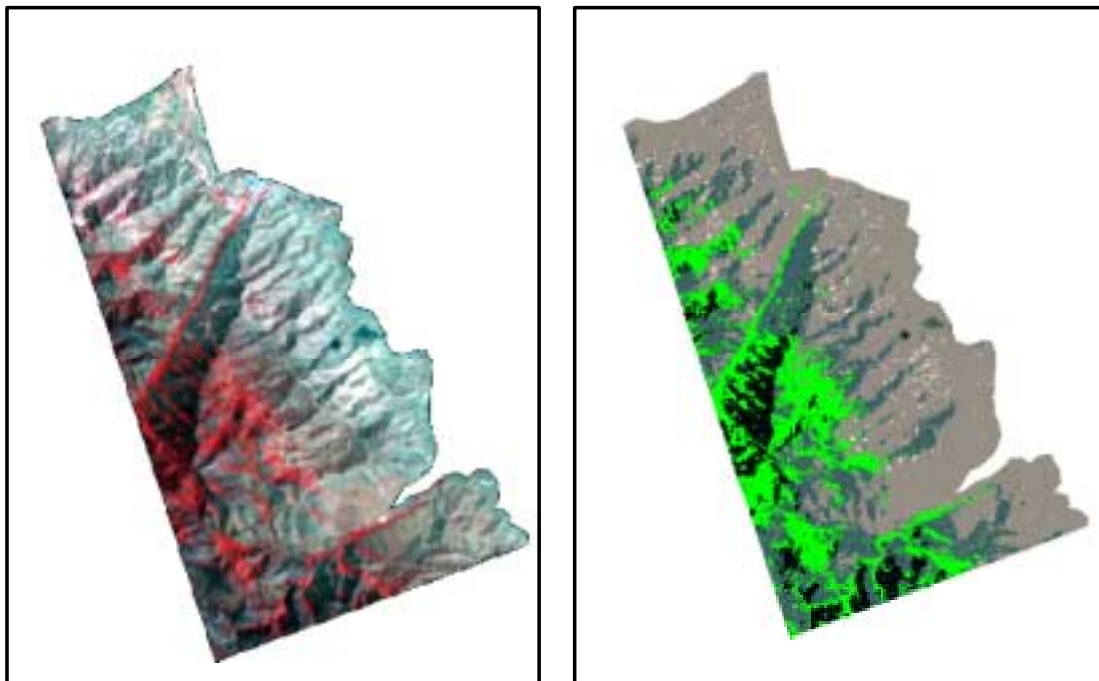


Figure 73. Landsat TM image classified by supervised classification (left) depicting forested area (highlighted, right).

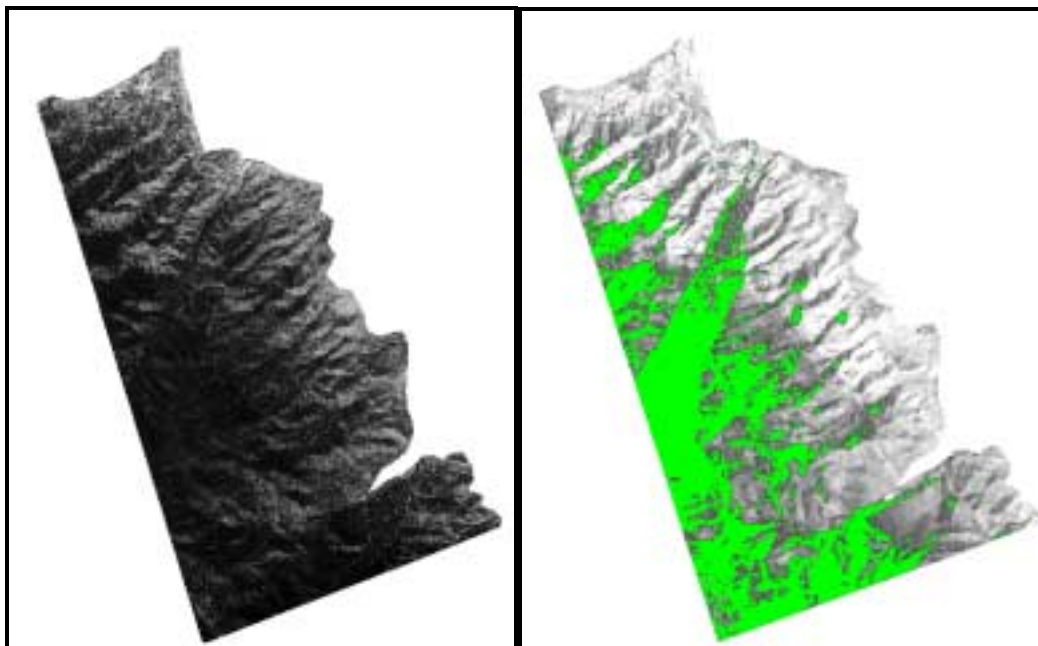


Figure 74. Corona image classified by supervised classification (left) with closest category for forested areas (right).

Conclusion. Regional Ecosystem and Forestry Manage unsupervised image-processing techniques alone are not useful for change detection, largely due to the panchromatic nature of Corona imagery. Corona panchromatic limitations allow confusion between shadows and dark forest. (Conifer trees reflect very little light when compared to other tree types.) Land cover type change analysis based on the Corona images alone is too inaccurate in a dry climate.

Visual analysis in conjunction with comparably dated Landsat Multi-Spectral Scanner (MSS) imagery promises to yield more accurate results (see section on Urban Land Use Change and Habitat Change Analyses). In addition, where the topography is less steep, the darker shades are more likely to reflect a true change in land cover (see section on Vegetation and Trend and Regional Ecosystem Management at Fort Benning, GA [page 87]).

Application Area: Determination of Predeployment Conditions

Installation location used. Sava River near Zupanj, Bosnia

Description of need for this analysis. The United States military often deploys overseas for training exercises, humanitarian operations, and emergency support as well as theater-of-operations actions. With each deployment, environmental concerns need to be taken into account when planning the operation, during execution, and after completion. In this case, when in operational status during the Bosnian conflict, North Atlantic Treaty Organization (NATO) troops (including U.S. Forces) built a temporary bridge (Figure 75) across the Sava River near Zupanja, a small city in the east of the Republic of Croatia on the border with Bosnia. When the bridge was no longer needed, the area was to be returned to its original condition. However, the question arose, “What was the original condition and when was it in this condition?”



Figure 75. Military vehicle rolling off a temporary ribbon bridge over the Sava River.

General description of procedure. Search and acquire image of appropriate location (<http://edcwww.cr.usgs.gov/Webglis/glisbin/guide.pl/glis/hyper/guide/disp>). Scan film. Examine image for baseline condition and characteristics.

Imagery resources required. Older imagery product. Date used was 23 June 1967 (Figure 76).

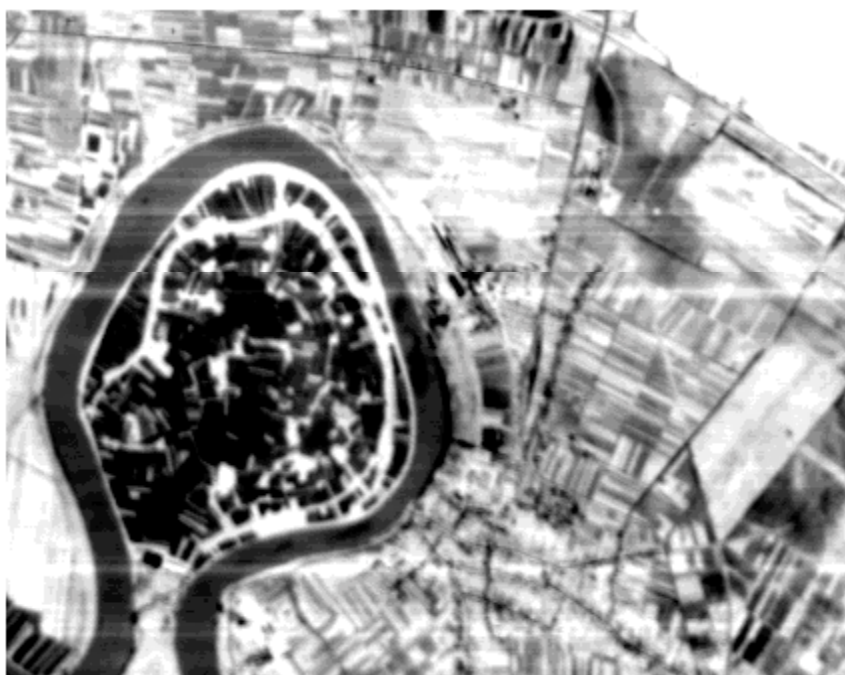


Figure 76. Image from a 1967 Corona film of the Sava River ribbon bridge crossing area.

Specific procedure. Search the USGS web site and order film of appropriate location. The film was scanned at 800 dpi, though the film grain would allow about 3600 dpi. Examination of the image for baseline conditions would allow an objective determination of at least some of the preexisting characteristics to about a 2-meter resolution. Primary in this case would be looking at the condition of the land near the location of the future crossing. When the question arises of what that location was like well before troops arrived, there would be less potential for disagreement. Also, it should be noted that the example here is of an old image. Others may be available either in the public or classified archives so investigators could obtain imagery much closer to a date before troops arrived than illustrated here. In this case, requesting an IDP (see Chapter 2) would allow more recent imagery to be examined at a less classified level.

Result. With all of the examples in this catalog of military installations, it is worth pointing out that archival imagery for most of the world is available and that that imagery has the potential to support United States interests.

Conclusion. Archival imagery for most of the world is available and can be put to use to provide an objective historical record for overseas actions.

Application Area: Determination of Predeployment Conditions

Installation location used. Peninsula near Phuket Island, Thailand

Description of need for this analysis. Yuma Proving Ground oversees as a subinstallation the Tropical Test Center (TTC). A need has been identified to provide additional overseas training capability for the TTC. The TTC in the Panama Canal Zone included Fort Clayton and Gambola Jungle Test Site. However, ownership of these facilities has been transferred to the Republic of Panama, so additional areas are being proposed. One of the proposed new areas for a TTC is on the southern peninsula of Thailand. For this example we examined two locations on the Thai peninsula near Phuket Island: one near Krabi and one on Ko Yao Yai Island (Figure 77) were chosen as examples of how the Corona archive may be used to set up a baseline of suitability and change detection. This particular analysis demonstrates the stereo character available due to the presence of forward- and aft-directed cameras.

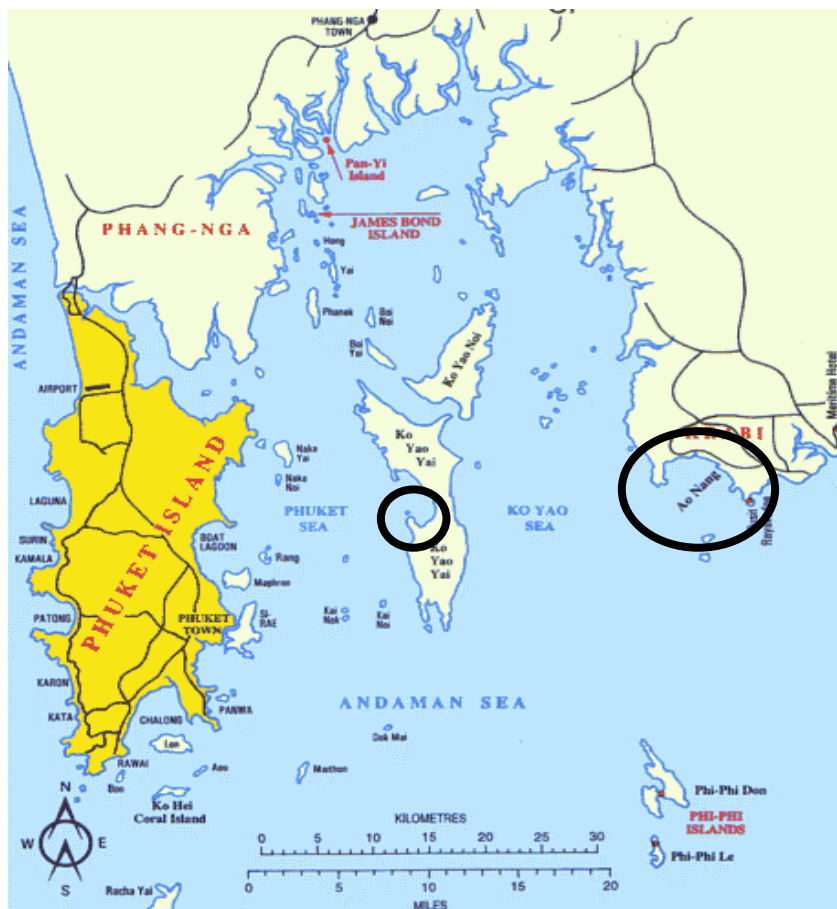


Figure 77. Location of two study areas.

General description of procedure. Search and acquire image of appropriate location. Scan film. Georeference scanned data. Examine image for baseline condition and characteristics.

Imagery resources required. Two archive films, one forward- and one aft-looking; make a stereo pair. Declassified imagery product dated 2 April 1967.

Specific procedure. This particular pair of films was ordered to display the stereo pair capabilities available within the film archive. As the Corona platform passed over an area, both a forward-facing and a rear-facing camera could take a picture. Putting the two together provides a 3-D effect when viewed with stereoscopic glasses. To accomplish this, small sections of the scanned image were clipped to a size where they could be laid conveniently next to each other. They were also georeferenced, though this was not a requirement for generating a stereo capability.

Result. Though Ko Yao Yai Island is somewhat level, some features can be seen in stereo. Looking at Figure 78 with stereo glasses, one can distinguish the cliff face and individual trees even though this image was taken by a satellite many miles above the earth.

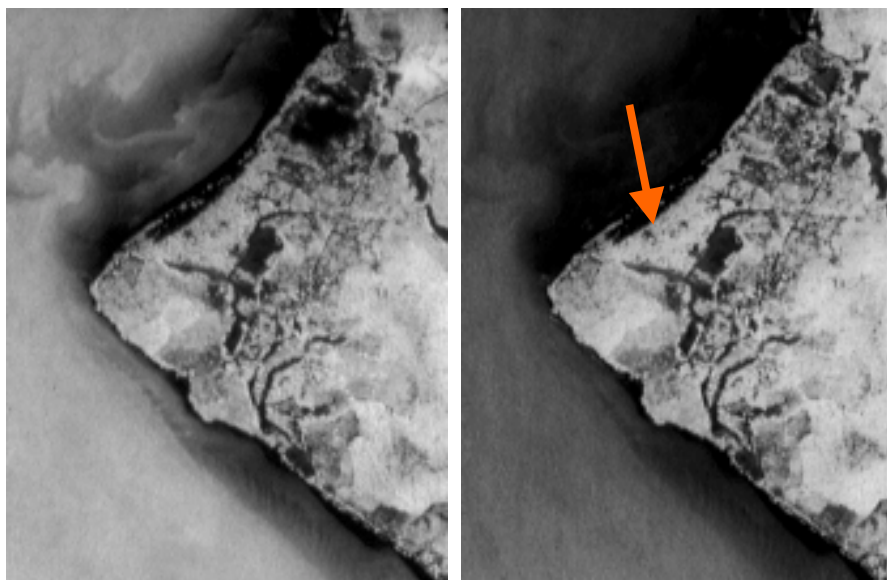


Figure 78. Stereo pair (forward image at left, aft image at right) showing 3-D effects at cliff face and on individual trees near arrow on Ko Yao Yai Island.

This application presented some interesting problems. Keep in mind that sources of digital cartography are difficult to find for Southeast Asia. The Digital Chart of the World (DCW) was used to georeference the image in Figure 79. The dashed line shows the coastline from the DCW. The georeferencing is only a

rough approximation because the Corona images are much more detailed than the DCW. A search on the Internet suggested that for Thailand, several commercial firms offered digital products that would be more acceptable for detailed analysis.

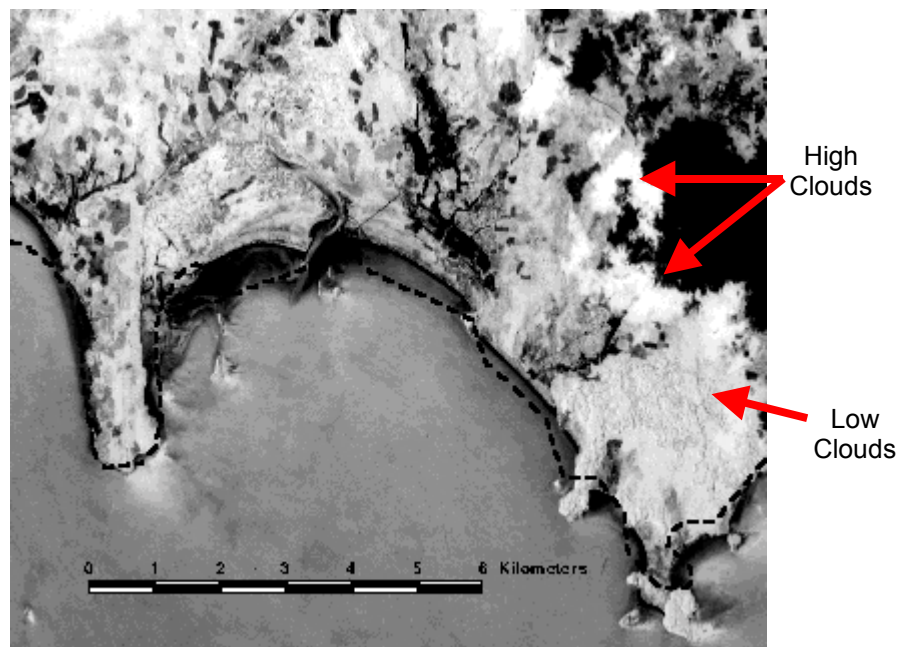


Figure 79. Image of Krabi showing some analysis problems.

The dashed line shows the coast according to DCW. Higher clouds are white, lower clouds mimic the coast and are gray and textured. Yet, fields and river dispersion are still visible in this low dpi scanned image.

In addition, this coastal area exhibited two types of clouds. For image processing, clouds generally are not desirable; but in this case the lower clouds mimicked the coastline so that the actual coast was occasionally difficult to distinguish.

Conclusion. The declassified archive of Corona imagery provides worldwide coverage of the land. Occasionally land managers have a need to access historical imagery to provide a baseline for non-theater actions. Often the imagery can be exploited to provide a stereo capability when examining the land characteristics. Though the Corona images are very detailed, resources to integrate them into a GIS data base overseas is more challenging than is true for continental United States locations where georeferenced digital material is readily available in a nonclassified environment.

Application Area: Discovery of Former Training Range Types

Installation location used. Fort A.P. Hill, VA

Description of need for this analysis. The identification of former firing ranges, particularly their former spatial extent, is an important question in determining an area's usefulness for other purposes. Occasionally records of the location or actual extent of ranges were never available or have become lost over time as there previously was no need to keep this information.

General description of procedure. The initial process involved the rectification of two Corona images, which fell within the boundary of the military installation. The Corona images and a Landsat TM image were processed using ERDAS Imagine 8.4. The processing involved rectifying the Corona images to the referenced Landsat TM image. The resampling procedure applied to this data set was the Nearest Neighbor resampling method. The boundary data and several supporting vector layers, such as the drainage network and road network, were used to provide a setting. A visual comparison of the Corona and Landsat TM image was then conducted.

Imagery resources required. Researchers used two Corona images, both dated December 1963, rectified to a reference Landsat 5 TM image (dated June 1994) in the UTM coordinate system (adopted from the Landsat image), with a Clarke 1866 projection system. Due to the extensive road network, it was fairly easy to locate a large number of ground control points.

Specific procedure.

1. Preprocessing:

Scan Corona filmstrip film at 5000 dpi

RMS: 847.71 for Corona transformation to UTM (DATUM/ZONE) based on TM

GCP: 50 for Corona transformation to UTM (DATUM/ZONE) based on TM

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: none

RMS: 735.14 for Corona transformation to UTM (DATUM/ZONE) based on TM

GCP: 40 for Corona transformation to UTM (DATUM/ZONE) based on TM

Geometric Correction Model: Polynomial Order: Second

Mosaicing Edge Matching Rule: none

Result. Forty to 50 ground control points were used to georeference each image; this number is about average.

1. **Analysis (Visual):** From a visual perspective, the 2-meter resolution of the Corona images proved to be rather pleasing to the eye, making it easy to recognize the firing range locations and develop a sequence of patterns (Figure 80). Firing range A (Figure 80, left) has a series of parallel dirt tracks that are clearly visible on the Corona image. This range was probably capable of accommodating a company-sized unit.

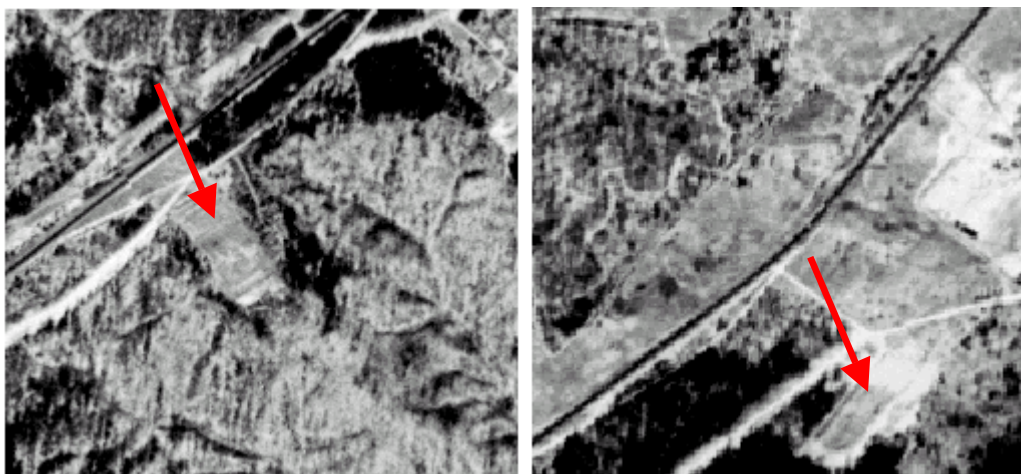


Figure 80. Corona image depicting firing range A (left) and firing range B (right).

Toward the ends of the range there is an indication of where weapons firing may have occurred. Firing range B (Figure 80, right) depicts an extensive track west of the training area. This range might also hold a company-sized unit.

The TM image, on the other hand, with resolution of 25-meters appeared blurred (Figure 81). Consequently, it is difficult to arrive at a definitive pattern. Computation of the dimensions was carried out with the aid of the measurement tool in ERDAS and made it possible to arrive at an estimated size of the firing ranges (Table 14). With the 2-meter resolution of the Corona image, it was practicable to clearly assess the boundary. In contrast, the 25-meter resolution of the TM image did not allow the boundaries to be clearly defined. From the analysis, firing range A (left) may exhibit an increase in area (possibly to accommodate an increased amount of activity). Firing range B (right) on the other hand showed only a slight increase in area.

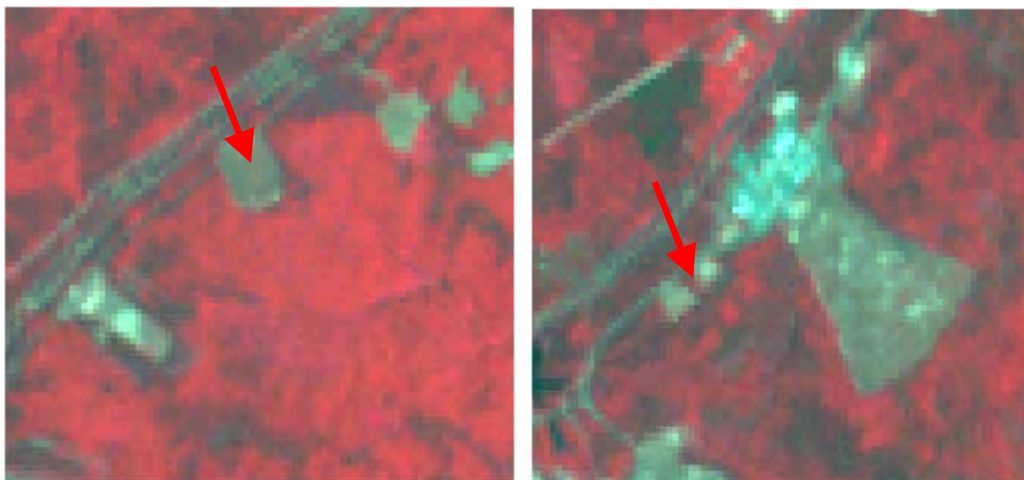


Figure 81. Landsat TM image depicting firing range A (left) and firing range B (right).

Table 14. Firing range location and dimensions.

	UTM-GRID	Area	Perimeter
Corona (A)	297485.98 / 4216627.47	10.74 acres	954.72 meters
Corona (B)	302537.59 / 4221097.88	4.914 acres	632.4 meters
TM (A)	297485.98 / 4216627.47	17.11 acres	1049.7 meters
TM (B)	302537.59 / 4221097.88	6.633 acres	658.6 meters

After a careful visual analysis of the entire area that fell within the boundary of the A.P. Hill military installation, a trend was observed and applied to the location of other training sites that would have been used for military training. The defining factor was a series of parallel dirt tracks that were clearly observed at other sites. These parallel tracks helped define the areas shown in Figure 82 as probable areas where military activity would likely have been carried out. Coupled with this factor, the dimension of these sites range from 4 to 12 acres. This size is in line with the other sites.

2. **Data Quality:** A meticulous review of the Corona data revealed features that are worth pointing out. The particular data set reviewed exhibited sections where deformities (in this case “pixel shifts”) were observed (Figure 83). It is suspected that this shift is a result of the georeference resampling algorithm and not in the film itself. This type of pixel shift can be observed in the georeferencing of other types of images (e.g., TM), however, it is usually not as apparent since the degree of detail is not as high as can be obtained with the Corona films.

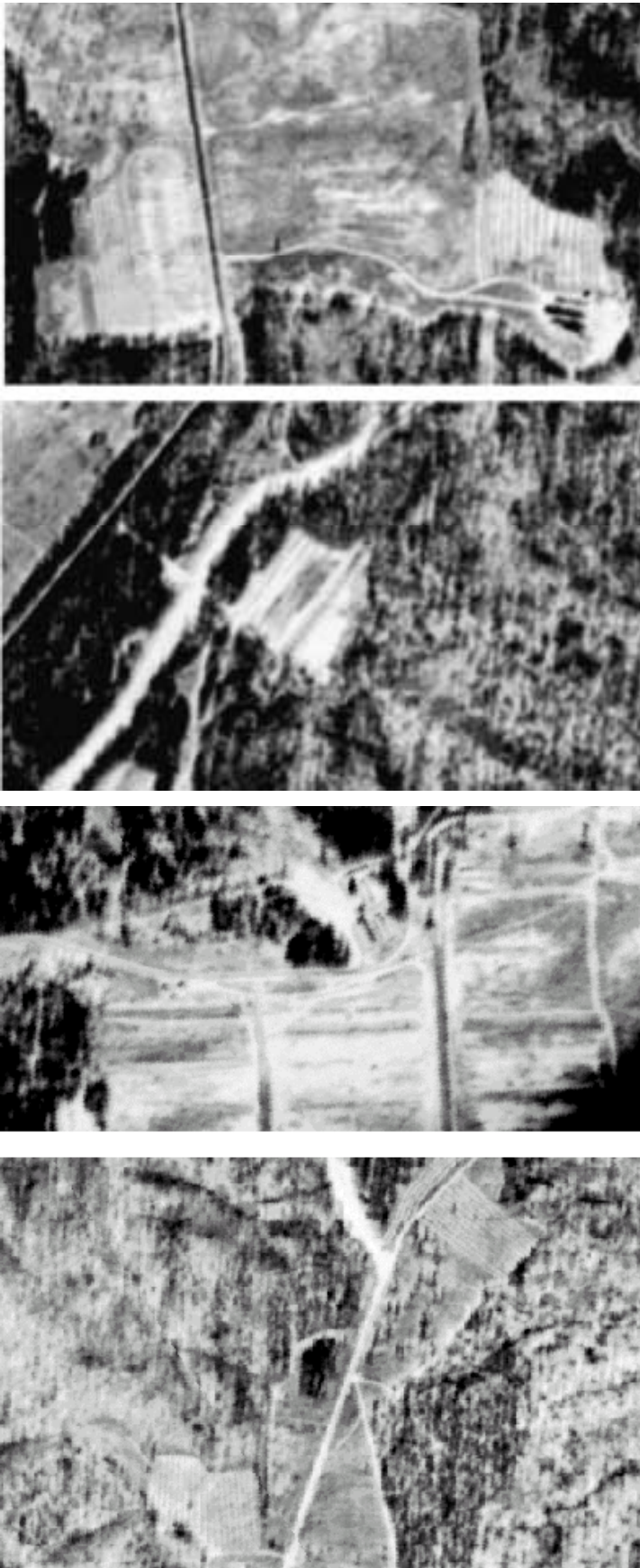


Figure 82. Probable training ranges/areas.



Figure 83. Depicts sections where there were strong indications of pixel shift.

Conclusions. The ability of both the Corona and Landsat TM data to support searches for old training ranges in a cost-effective manner has been illustrated. Though the TM data provides a unique multispectral capability that serves to enhance the information derived from the Corona data, the high resolution of the Corona data lends itself well to visual reconnaissance for old range identification and character analysis.

Application Area: Cultural Resources Investigations

Installation location used. Edwards Air Force Base, CA

Description of need for this analysis. DoD installations have a requirement under provisions of Federal law and regulations to manage and preserve historical and archeological resources present on installation lands. To comply with the law and regulations, the Environmental Directorate at Edwards Air Force Base must survey base lands to find and preserve cultural resources of the prehistoric and historic eras before the U.S. Government acquired the land for government purposes. At present, only about 25 percent of the base has been surveyed adequately to identify areas with resources that must be investigated. High-resolution aerial photography, when available, can be an important tool for locating potential cultural resources or areas with high probability for cultural resources.

General description of procedure. The high-resolution classified imagery is used by Environmental Directorate personnel or contractors with appropriate clearances to find surface features that are indicators of the possible existence of surface and subsurface cultural resources. The results of the application of the imagery are used to determine if and where to deploy personnel on the ground to investigate potential sites using ground-based methods.

Imagery resources required. High-resolution classified images.

Result. Personnel with cultural resources expertise examined the images and noted several features that indicated a high potential for the presence of cultural resources. These sites were then scheduled for on-the-ground investigation.

Conclusion. High-resolution classified imagery can be a useful source of information for locating potential cultural resources sites at Edwards Air Force Base. This imagery can be a very effective way to survey base lands to help direct where to deploy personnel for on-the-ground surveys and make the most cost-effective use of personnel time.

4 Conclusions and Recommendations

The Imagery

Declassified

General characteristics of the declassified data available to the public:

1. Satellites were regularly imaging much of the United States almost from the beginning of their missions (as early as 1960).
2. Black and white photographic products of very high resolution for most installations in the United States can be expected to be available beginning in 1961 and ending in 1972, after which imagery remains classified.
3. Acquisition cost is minimal and many locations have the in-house resources to process the photographic material into digital form.
4. Enough data exists that we may confidently make the statement that some images will exist for most installations within the United States.
5. For many installations that do not have an alternative source of historical imagery, declassified and (potentially) still classified imagery is a unique archive that was not previously available.

The images from the USGS are contact prints, enlarged prints, or contact transparencies. If not already enlarged, the products can be visually inspected like air photographs. They are very detailed and often can be inspected with a microscope to an enlargement of up to 36 times. Many times this is adequate to answer specific questions about land use change such as searching for locations of old storage facilities. For example, Figure 84 shows roads and individual storage huts at Dugway Proving Ground, even through a light cloud cover, after the image was enlarged.

To use an image within a GIS/Image Processing System, it will have to be scanned and the resulting file georeferenced. The images are highly detailed and for the Corona KH-4A and KH-4B systems, scans will result in ground resolutions in the 2- to 3-meter range to result in about a 1:15,000 or 1:20,000 scale map product. Installations may consider preprocessing Corona negatives by first scanning, then registering them to a USGS base and tiling them into a series similar to USGS DOQ products.

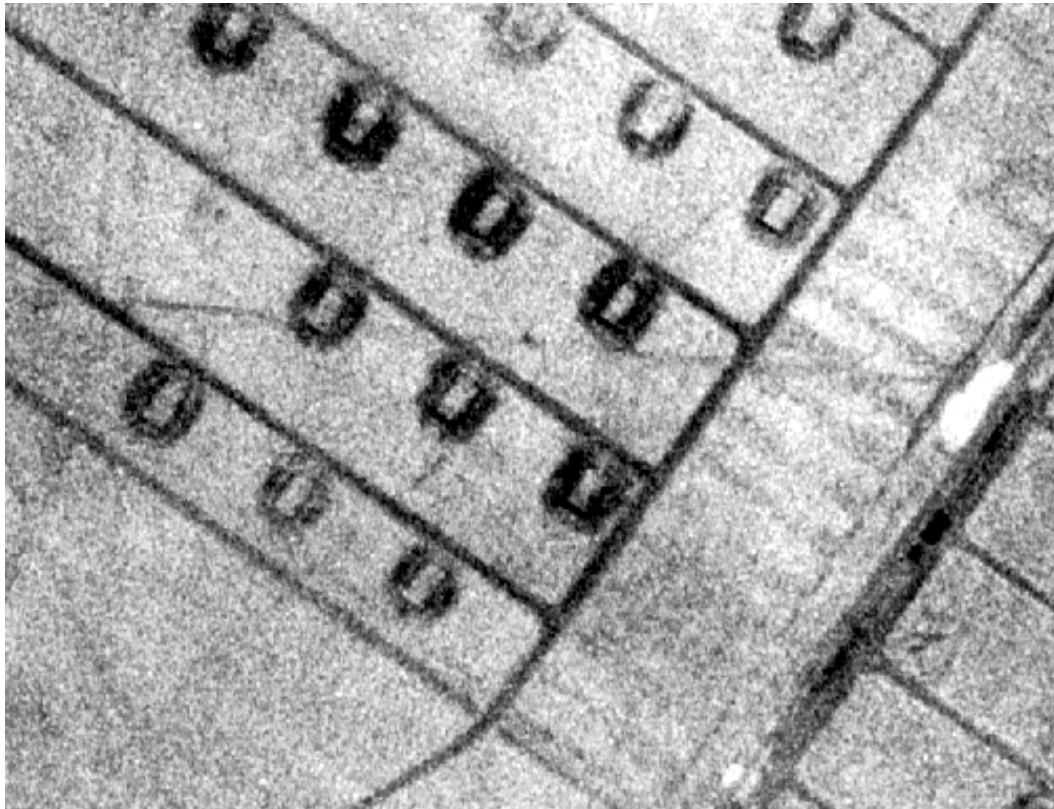


Figure 84. Storage facilities at Dugway Proving Ground on 4 April 1967.

The major advantages to Corona imagery are its temporal and spatial coverage and its relatively even film exposure. For many installations that do not have an alternative source of historical imagery, this is a unique archive.

Disadvantages of the Corona imagery include:

1. It was developed for visual inspection. The Keyhole systems operated this way for many years before the current GIS technology was available. Digital use requires additional steps and some accommodation to the material's limitations.
2. Since it is an archival product, you get only what is available. You cannot request season, time, or tide levels, for example. Many images are cloudy; some are poorly exposed and imagery is not available for all installations.
3. The product is a single-band panchromatic (black and white) film. Therefore differentiation of land types based on spectral characteristics in different bands cannot be performed as can be done with Landsat MSS or TM images.
4. It is a film product. Films have to be scanned into digital form and georeferenced to be input to a GIS to be used with other themes and imagery. The film is not a stable base (it will and has warped slightly), so scanning at the film grain limit will allow problems with registration to occur. Another way of saying this is that the images are as detailed as some aerial photography, but do not use the quality of materials normally expected in aerial photography.

5. Images are so detailed that problems with registration (which could be ignored before e.g., with TM and MSS) cannot be ignored with the Corona imagery. Registered Corona images also show many mistakes in the USGS 7.5-Minute Quadrangles, which were easily ignored before.

Declassified images can be easily found via the web at the USGS EROS Data Center in Sioux Falls, SD. Availability can be quickly determined and with browse images, cloudiness can be evaluated. We found that the web site presents browse images that are occasionally not of the image you order. Images are inexpensive; scanning is not too expensive (roughly \$150 per one-fifth of a film strip at 5000 dpi). Georeferencing is time consuming.

As a rough survey of availability of coverage for military installations, we found that for a particular location, about 30 items were potentially available in the archive. Of these, on the average 7 would be cloudy, 22 would be poorly centered, and two would be acceptable. Coverage ranged from 1961 to 1972; basically over the entire temporal span of the archive.

For this project, we ordered over 80 filmstrips. We scanned about 20 of them at high detail. We georeferenced about a dozen of those. These were the primary files used in the sample applications. We found that using the Corona images in conjunction with SPOT or Landsat images usually provided the best combination of resources. For generating historical land use maps, visual interpretation was often more reliable than automatic classification techniques.

Classified

A description of the characteristics of the imagery that is still classified cannot be covered in this document. Of course the United States continued its satellite missions after the 1960s, and there is movement to decrease the classification level on this newer material. Declassification has been in review for several years but the material remains classified. In general, it can be said that:

- This material exists after 1972.
- It is panchromatic (black and white) film-equivalent material.
- Handling it would require a secure facility.
- Coverage is likely to be similar to the material already declassified.
- The same techniques and limitations illustrated in these examples are likely to apply to the classified imagery.

For a more detailed description of the character of the images that might be available, see *National Security Archive Electronic Briefing Book No. 13: U.S. Satellite Imagery, 1960-1999* at:

<http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB13/index.html>

The classified material can be requested in the DoD by applying to the Civil Applications Committee. Applications and uses of this data (with limited exceptions) will always have a secondary priority to intelligence issues. Therefore, requests by land managers will rarely be given priority. It is the law that these assets cannot be used to monitor U.S. persons. This implies that by limiting requests to Federal land, such as DoD installations, asset acquisitions should be easier. Because the DoD is highly involved with operation of these assets, DoD land managers go through an entirely separate request procedure than any other Federal agency. All other agencies go through the USGS. DoD agencies (e.g., installation land managers) go through their service-appointed CAC. This means that requests based on land management will be reviewed along with other requests that have an intelligence issue. Experience suggests that this results in very slow response, additional documentation, and possibly a request refusal. The Imagery Policy and Security Subcommittee (IPSCOM) tends to recommend that nonclassified commercial resources be used instead of classified imagery, even when no adequate commercial alternative exists.

For many installations, the staff time resources may be too limiting to pursue this application process. An alternative is to hire a contracting firm that has successfully generated Imagery-Derived Products (IDPs) for their customers. In this case, greater funding will be required. Qualified contractors can and have acted as representatives of a tasking Federal agency.

If the application requires classified imagery support, it should be recognized that the labor, time, and resource commitment to handle these materials will be much greater than one normally experiences. If the application requires the earliest imagery for a given location, the unclassified material should fulfill the needs adequately. If you need latter archival imagery or need to request the acquisition of new imagery, expect a much longer response time than is characteristic of unclassified imagery. In this document, the applications used the declassified imagery as surrogates for classified imagery.

Specific Application Areas

For each of the general application areas, we can make the following statements about the applicability and versatility of the satellite imagery based on the examples carried out for this project.

The applications are not intended to be the actual solution to a real problem at the installation. Rather, they are intended to demonstrate the capability to support such an application. The use of imagery from a particular installation for a particular application is not intended to suggest that the installation actually had such a problem. Though these applications parallel real problems, they are not necessarily addressing real problems at the particular installation.

Urban Land Use Change Analysis

For the purpose of detecting land use change, the Corona films offer some opportunities, as well as limitations. Quantifiable changes in the types of land use can be determined with good confidence because of the high resolution of the images. For example, the 1964 image in Figure 85 shows an old baseball diamond at Fort Irwin. Important indices of natural condition, such as encroachment due to road building can also be quantified. Changes in natural areas such as grassland and scrub to mesquite land cover require more spectral and spatial resolution than the Corona images can provide, but the Corona images may be used to visually interpret the land cover when complemented with a Landsat image from a similar time.



Figure 85. Fort Irwin image from 1964.

Habitat Change Due to Road Encroachment Analysis

Combining the detail of the Corona imagery with the spectral information in a Landsat MSS image is a useful means of developing habitat extent in the 1960s. For example, the October 1964 image of Fort Benning in Figure 86 clearly shows a forest edge defined by a small road. Later civil imagery from the Landsat MSS program will not provide the detail needed to see local road or training trail locations. It was illustrated that professional photographic interpretation input in the development of a model was a needed requirement. Simple automatic computer evaluation is not adequate.

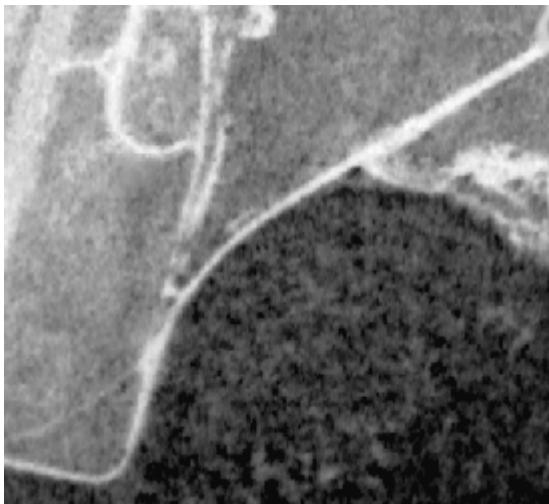


Figure 86. Wildlife managers may need to follow the development of roads to determine the effect on habitat.

Visualization Integration

In addition to quantitative use, Corona imagery can play a valuable role in generating visualizations of land use change. For this purpose, Corona imagery is significantly easier to use than historic aerial photography because of its broad extent and relatively even exposure. The technique of draping historic Corona imagery over a terrain model and dissolving back and forth to current orthophotography can be used to generate land use change visualizations that are readily understood by a nontechnical audience and therefore can provide the impact needed to emphasize an idea or point.

Vegetation and Trend Analysis and Extending Management and Climate Change Trend Analysis Baselines

The Corona imagery provides an outstanding and unique source for identifying characteristics of simple vegetative change. In the example application in the Southwestern United States, white spots on the surface were easy to identify accurately. For this use, the Corona image is superior to the Landsat TM image, which does not provide the resolution required to identify the location of these white spots. Landsat TM imagery, however, can provide information as to the conditions that contribute to the spotting.

It is extremely unlikely that the areas of spotting are caused by man-made activities. Based on the information provided from the Corona and TM imagery, it is most likely that the white spots are caused by natural events, such as vegetation disappearance. If the cause of the spotting is due to vegetation change, this could be an indicator of climatic change for this region, most likely to a drier climate.

The Corona images can be used to statistically identify areas that are likely the best locations for more detailed analyses. Users should be aware that the Corona film contains anomalies, most likely caused by dust on the film when developed or scanned to digital format. In this application, the visual appearance of these anomalies was similar to the white spotting under investigation. However, statistical evaluation of the shape and size of the anomalies could be used to separate them from the spotting under investigation.

Wetland and Land Carrying Capacity for Military Use

The shoreline length and extent of ponds and wetlands can be easily measured. Based on this, an increase or decrease in the overall shoreline area can be determined and compared between the installation and nearby private lands. However, due to tides, seasons, and ocean currents, it is important to control these variables when acquiring images to compare. In this example application, wetlands on the installation exhibited wetland recovery and even increased while State-owned lands did not show a change.

As demonstrated, the Corona image provides valuable historical information of the land cover type and changes in land use. Not only can it document land use difference in a specific area, but also probably shows differences in land management practices due to ownership.

Shoreline boundaries are difficult to determine due to the inability to distinguish waves from beach in a panchromatic Corona image. It is recommended that the Corona imagery be inspected visually rather than automatically.

Discovery of Former Training Range Types

The ability of both the Corona and Landsat TM data to support searches for old training ranges in a cost-effective manner has been illustrated. Though the TM data provides a unique multi-spectral capability that serves to enhance the information derived from the Corona data, the high resolution of the Corona data lends itself well to visual reconnaissance for old range identification and character analysis.

Vegetation and Trend Analysis and Support for Regional Ecosystem Management - Humid Environment

The example on the East Coast focused on identifying natural land cover change over the long term. Marsh/wetlands and water bodies could be easily identified using the Corona images. The wetlands and water also provided an excellent and reliable resource for the identification of classes for TM and SPOT images. The Corona images are more valuable for identifying land classes than those derived from UGSG 7.5-Minute Quadrangles.

Support for Regional Ecosystem Management - Arid Environment

For Regional Ecosystem and Forestry Management, unsupervised image-processing techniques alone are not useful to detect change, largely due to the panchromatic nature of the Corona imagery. Corona panchromatic limitations allow confusion between shadows and dark forest. (Conifer trees reflect very little light when compared to other tree types.) Land cover type change analysis based on the Corona images alone is too inaccurate in a dry domain. In a panchromatic image, urban and barren areas are easily confused if only automatic analysis is used. Visual analysis in conjunction with comparably dated Landsat MSS imagery yields more accurate results. In addition, where the topography is less steep, the darker shades are more likely to reflect a true change in land cover.

Forestry Management

Corona images provide a potentially good historical record of areas where fires are likely to have occurred. They may serve as a guide to locating potential burned areas. However, due to the panchromatic nature of Corona images, de-

termining the difference between burned forest and bare areas is difficult. The resultant statistical error level is too high to have confidence in the use of a supervised classification to locate other burned areas in the Corona image. Additional information sources will have to be used to verify suspected burned areas. However, problems with using a TM image include the large temporal lapse between images (at least 10 years, usually much more) and the gross spatial resolution of the TM image (28.5 m).

Discovery of Disposal Sites - Arid Environment

The Corona imagery is capable of tracking and detecting deposits of wind-borne material and so can provide a clue to potential unrecorded testing locations. Because these features exist only on the Corona images and cannot be seen even with much later TM imagery, they afford a unique resource of wind and military testing activity, particularly at installations within a dry climate (i.e., Fort Irwin) during the 1960s (Figure 87).



Figure 87. Corona images can be used to find old storage locations (lower right) or old range firing locations (upper right) at installations.

Discovery of Disposal Sites - Humid Environment

Because of the high resolution offered by the archival Corona imagery and the more recently generated DOQQ images, locations of and spatial coverage of disposal sites can be determined. The analysis could be improved by the addition of a robust GIS database. Finding such locations is more difficult in a humid climate where the presence and quick growth of vegetation allows the fingerprints from disposal activities to more quickly disappear.

Extending Management and Climate Change Trend Analysis Baselines and BRAC Support

Based on the visual results of the data used in this analysis, Corona data provides a creditable and reliable base for determining use change. In spite of the panchromatic limitations of the original films, Corona images can be used as a completely reliable method to identify or establish a land cover character baseline (Figure 88, Fort Irwin, 1965). This can be used to compare a current situation of intense training to a situation before military acquisition.

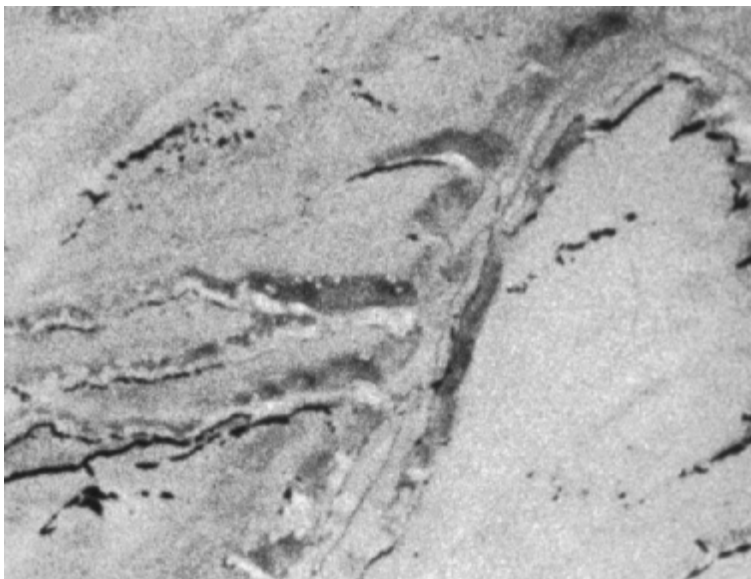


Figure 88. Using Corona images, it is feasible to follow changes in locations that are potentially susceptible to erosion.

Determination of Predeployment Conditions, Overseas

The declassified archive of Corona imagery provides worldwide coverage. Occasionally land managers have a need to access historical imagery to provide a baseline for non-theater actions. The imagery can sometimes be exploited to provide a stereo capability when examining the land characteristics. Figure 89 shows Ko Yao Yai Island, Thailand, where a stereo pair of images was used to show 3-D effects. Though the Corona images are very detailed, resources to integrate them into a GIS data base overseas is more challenging than is true for within the United States locations where georeferenced digital material is readily available in a nonclassified environment.

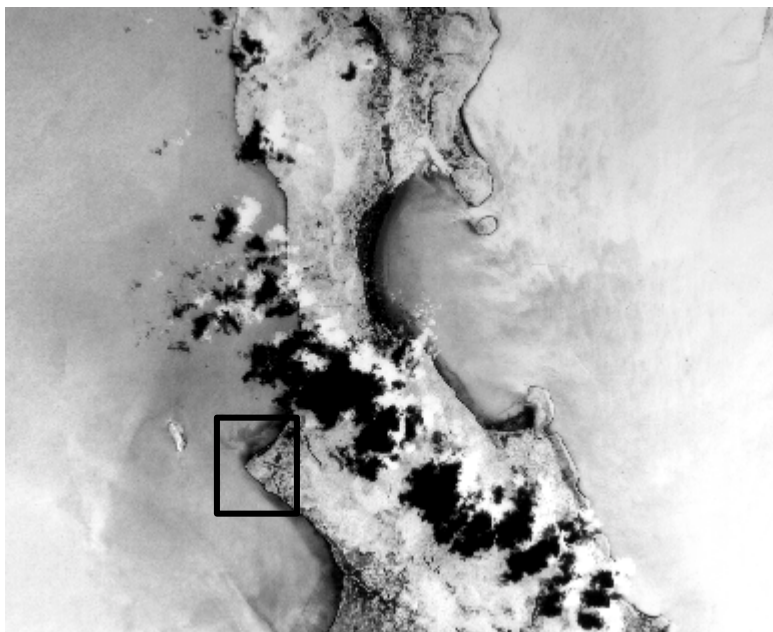


Figure 89. Ko Yao Yai Island, Thailand and the location used in the stereo pair application to show 3-D effects.

Cultural Resources Investigations

High-resolution classified imagery can be a useful source of information for locating potential cultural resource sites. This imagery can be a very effective way to survey base lands to help direct where to deploy personnel for on-the-ground surveys and make the most cost-effective use of personnel and time.

Aquatic Habitat Monitoring and Mapping

Analysis of the classified imagery indicated that this resource could provide very useful data to supplement other unclassified data sources for monitoring and mapping purposes.

Endangered Species Habitat Monitoring

Classified imagery would greatly help overcome the difficulties and constraints associated with on-ground monitoring of the habitats that are normally inaccessible.

Oil Spill Damage in an Estuarine Environment

Classified imagery is a useful resource for helping to determine the extent of ecological damage from oil spilled into the environment.

Conclusions and Recommendations

Military land managers can benefit greatly from the use of both classified and declassified satellite imagery. Most of this report has dealt with the character and applications that can be derived from the declassified imagery now available at the USGS EROS Data Center under the broad heading “Corona Satellite Photography.” The examples provided here using the declassified imagery should give the user an idea of the potential and limitations of both types of imagery.

In general, many of those applications that military land managers had previously identified as being of interest (Lozar et al. 2000) can be supported using this imagery. Effectiveness is likely to increase if the imagery is used in conjunction with other data and imagery types. The main advantage of the classified/declassified imagery is its extremely high resolution. The main disadvantage is that it is panchromatic. If the application of interest deals with generating a temporal baseline from the past, the declassified imagery offers very high resolution, ease of access (including low cost), and interpretation. If you need latter archival imagery or need to request the acquisition of new imagery, both of which are in the classified realm, expect a much longer response time than is characteristic of civil use imagery.

Because the DoD is highly involved with operation of the platforms and instruments that provide these imagery assets, DoD land managers go through a different request procedure than any other Federal agency. All other agencies go through the USGS. DoD agencies (e.g., installation land managers) go through their service-appointed CAC. This means that land manager requests are reviewed along with other requests that have an intelligence issue. Experience suggests that this results in very slow response, additional documentation, and possibly a request refusal. For many installations, the staff time resources may be too limiting to pursue the application procedure. This is not the experience of land managers in other Federal agencies who make their requests through the USGS. It seems likely that military land managers going through a USGS CAC would find this a more responsive route and in closer harmony with the intent of the Environmental Imagery Derived Products (EIDP) Program. However, this route is not currently available to DoD land managers. An alternative is to hire a contracting firm that has successfully generated IDPs for their customers.

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Appendix A: Executive Order #12951: Release Of Imagery Acquired By Space-Based National Intelligence Reconnaissance Systems

Executive Order
#12951

Release Of Imagery Acquired By Space-Based National **Intelligence** Reconnaissance Systems

By the authority vested in me as President by the Constitution and the laws of the United States of America and in order to release certain scientifically or environmentally useful imagery acquired by space-based national **intelligence** reconnaissance systems, consistent with the national security, it is hereby ordered as follows:

Section 1. Public Release of Historical **Intelligence** Imagery. Imagery acquired by the space-based national **intelligence** reconnaissance systems known as the Corona, Argon, and Lanyard missions shall, within 18 months of the date of this order, be declassified and transferred to the National Archives and Records Administration with a copy sent to the United States Geological Survey of the Department of the Interior consistent with procedures approved by the Director of Central **Intelligence** and the Archivist of the United States. Upon transfer, such imagery shall be deemed declassified and shall be made available to the public.

Sec. 2. Review for Future Public Release of **Intelligence** Imagery. (a) All information that meets the criteria in section 2(b) of this order shall be kept secret in the interests of national defense and foreign policy until deemed otherwise by the Director of Central **Intelligence**. In consultation with the Secretaries of State and Defense, the Director of Central **Intelligence** shall establish a comprehensive program for the periodic review of imagery from systems other than the Corona, Argon, and Lanyard missions, with the objective of making available to the public as much imagery as possible consistent with the interests of national defense and foreign policy. For imagery from obsolete broad-area film-return systems other than Corona, Argon, and Lanyard missions, this review shall

be completed within 5 years of the date of this order. Review of imagery from any other system that the Director of Central **Intelligence** deems to be obsolete shall be accomplished according to a timetable established by the Director of Central **Intelligence**. The Director of Central **Intelligence** shall report annually to the President on the implementation of this order.

(b) The criteria referred to in section 2(a) of this order consist of the following: imagery acquired by a space-based national **intelligence** reconnaissance system other than the Corona, Argon, and Lanyard missions.

Sec. 3. General Provisions.

(a) This order prescribes a comprehensive and exclusive system for the public release of imagery acquired by space-based national **intelligence** reconnaissance systems. This order is the exclusive Executive order governing the public release of imagery for purposes of section 552(b)(1) of the Freedom of Information Act.

(b) Nothing contained in this order shall create any right or benefit, substantive or procedural, enforceable by any party against the United States, its agencies or instrumentalities, its officers or employees, or any other person.

Sec. 4. Definition. As used herein, "imagery" means the product acquired by space-based national **intelligence** reconnaissance systems that provides a likeness or representation of any natural or man-made feature or related objective or activities and satellite positional data acquired at the same time the likeness or representation was acquired.

William J. Clinton

The White House,
February 22, 1995.

Appendix FGUO1: IDPs Standard Products (Appendix FGUO1 is for Government Use Only)

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Appendix FGUO2: General Examples (Appendix FGUO2 is for Government Use Only)

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